

JANUARY 1961



VOL. 53 • NO. 1

# Journal

## AMERICAN WATER WORKS ASSOCIATION

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**1961 AWWA CONFERENCE**  
**Detroit, June 4-9**

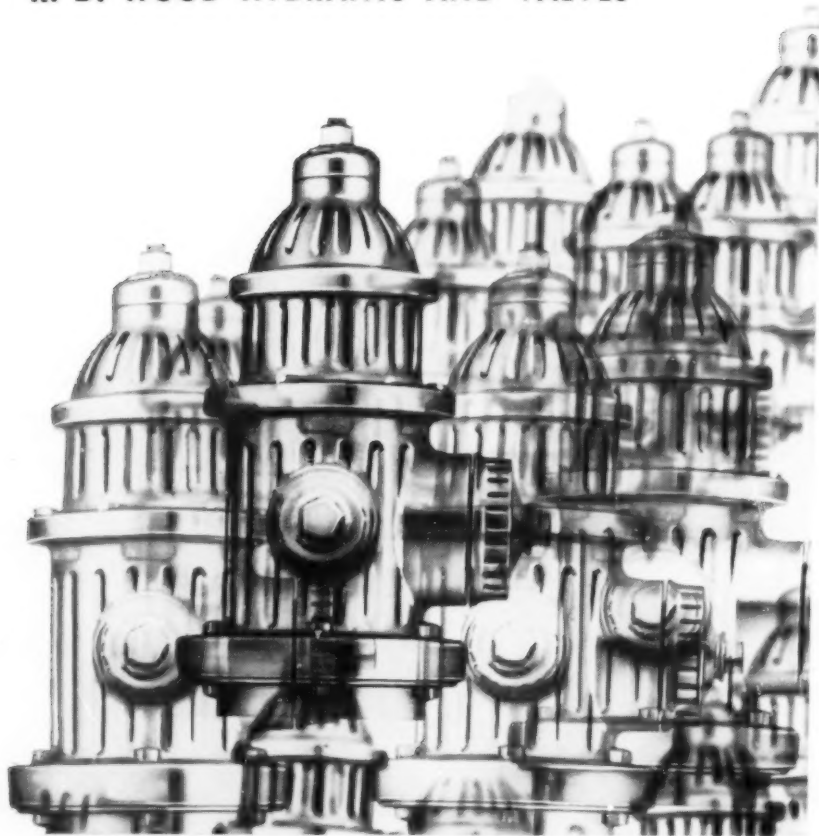


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# Journal

AMERICAN WATER WORKS ASSOCIATION

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Phone: MUrray Hill 4-6686

January 1961

Vol. 53 No. 1

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Fig. 1

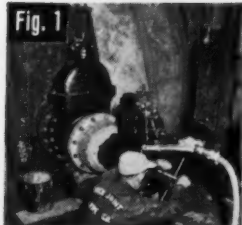


Fig. 2

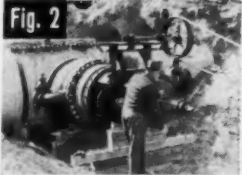


Fig. 3



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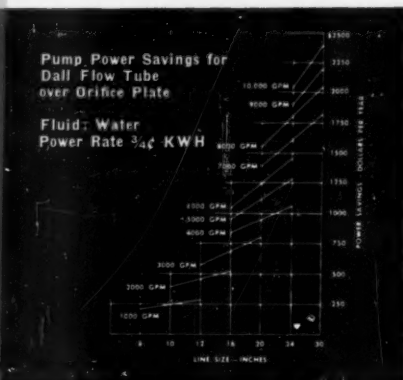
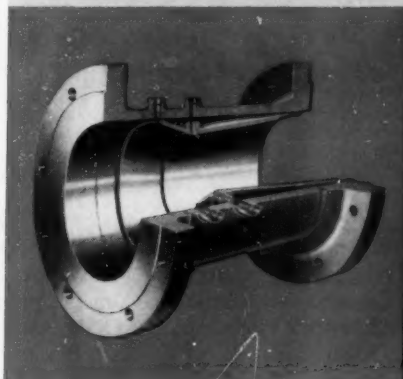
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**June 4-9, 1961**

Official reservation forms are being mailed to all members this month.



## *Coming Meetings*

### **AWWA SECTIONS**

#### **Spring 1961**

**Jan. 24**—New York Section, Mid-winter Luncheon Meeting, at Park Sheraton Hotel, New York. Secretary, Kimball Blanchard, Neptune Meter Co., 2222 Jackson Ave., Long Island City 1.

**Feb. 1-3**—Indiana Section, at Sheraton-Lincoln Hotel, Indianapolis. Secretary, Chester H. Canham, State Board of Health, 1330 W. Virginia St., Indianapolis.

**Feb. 8**—New Jersey Section, Winter Luncheon Meeting at Hotel Essex House, Newark. Secretary, A. F. Pleibel, Dist. Sales Mgr., R. D. Wood Co., 683 Prospect St., Maplewood.

**Mar. 16**—New England Section, at Tufts University, Medford, Mass. Secretary, Ralph M. Soule, San. Engr., State Dept. of Public Health, Boston, Mass.

**Mar. 22-24**—Illinois Section, at LaSalle Hotel, Chicago. Secretary, Dewey W. Johnson, Research Engr., Cast Iron Pipe Research Assn., 3440 Prudential Plaza, Chicago 1.

**Apr. 5-6**—West Virginia Section, at West Virginian Hotel, Bluefield. Secretary, Hugh W. Hetzer, Design & Construction Dept., Union Carbide Chemicals Company, Box 8361, South Charleston.

**Apr. 6-8**—Montana Section, at Placer Hotel, Helena. Secretary, A. W. Clarkson, Asst. Director, Div. of Environmental Sanitation, State Board of Health, Helena.

**Apr. 11-13**—New York Section, at Statler-Hilton Hotel, Buffalo. Secretary, Kimball Blanchard, New York Branch Sales Office, Neptune Meter Co., 22-22 Jackson Ave., Long Island City 1.

**Apr. 12-14**—Kansas Section, at Baker Hotel, Hutchinson. Secretary, Harry W. Badley, Representative, Neptune Meter Co., 119 W. Cloud, Salina.

**Apr. 14**—California Section, at Biltmore Hotel, Santa Barbara. Secretary, Frank F. Watters, Hydr. Engr., State Public Utilities Com., State Bldg., Civic Center, San Francisco.

**Apr. 19-21**—Nebraska Section, at Cornhusker Hotel, Lincoln. Secretary, Joseph J. Rossbach, Metropolitan Utilities, 18th & Harney Sts., Omaha.

(Continued on page 8)



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**Coming Meetings**

(Continued from page 6)

**Apr. 20-22**—Arizona Section, at San Marcus Hotel, Chandler. Secretary, A. D. Cox, Jr., Secy. & Comptroller, Arizona Water Co., Box 5347, Phoenix.

**Apr. 23-26**—Southeastern Section, at Poinsett Hotel, Greenville, S.C. Secretary, N. M. deJarnette, 96 Poplar St., N.W., Atlanta, Ga.

**Apr. 26-29**—Pacific Northwest Section, at Empress Hotel, Victoria, B.C. Secretary, Fred D. Jones, W. 2108 Maxwell Ave., Spokane, Wash.

**Jun. 1-3**—Canadian Section, at Prince Edward Hotel, Windsor, Ont. Secretary, A. E. Berry, 72 Grenville St., Toronto, Ont.

**Jun. 20-22**—Pennsylvania Section, at Galen Hall Hotel, Wernersville. Secretary, L. S. Morgan, 413 First National Bldg., Greensburg.

**Fall 1961**

Sep. 11-13—Kentucky-Tennessee Sec., Louisville, Ky.

Sep. 13-15—New York Sec., Saranac Lake.

Sep. 13-15—North Central Sec., St. Paul, Minn.

Sep. 20-22—South Dakota Sec., Rapid City.

Sep. 27-29—Wisconsin Sec., Milwaukee.

Oct. 1-3—Missouri Sec., Springfield.

Oct. 4-6—Virginia Sec., Roanoke.

Oct. 8-11—Alabama-Mississippi Sec., Biloxi, Miss.

Oct. 15-15—Southwest Sec., San Antonio, Tex.

Oct. 18-20—Iowa Sec., Cedar Rapids.

Oct. 25-27—California Sec., Sacramento.

Oct. 25-27—Ohio Sec., Toledo.

Oct. 25-28—New Jersey Sec., Atlantic City.

Oct. 29-Nov. 1—Florida Sec., Orlando.

Nov. 1-3—Chesapeake Sec., Baltimore, Md.

**OTHER ORGANIZATIONS****1961**

Jan. 29-Feb. 3—AIEE Winter General Meeting, New York, N.Y.

Jan. 29-Feb. 3.—ASTM Committee Week, Netherland Hilton Hotel, Cincinnati, Ohio.

Jan. 31-Feb. 1—3rd Sanitary Engineering Conference, University of Illinois, Urbana, Ill., cosponsored by the State Department of Public Health and the university's Department of Civil Engineering. Write: Ben B. Ewing, Assoc. Prof. of San. Eng., Univ. of Illinois, Urbana.

Mar. 13-17—National Assn. of Corrosion Engineers, Statler Hotel, Buffalo, N.Y.

**SHORT COURSES****1961**

Jan. 23-Feb. 3—Course on "Basic Radiological Health," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Feb. 9-10—Short course on "Coagulation of Water for Filtration," cosponsored by the University of Michigan and the Michigan Section, AWWA. Write: Harry E. Miller, Director, Continued Education, School of Public Health, Univ. of Michigan, Ann Arbor.

Feb. 13-17—Course on "Radioactive Pollutants in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

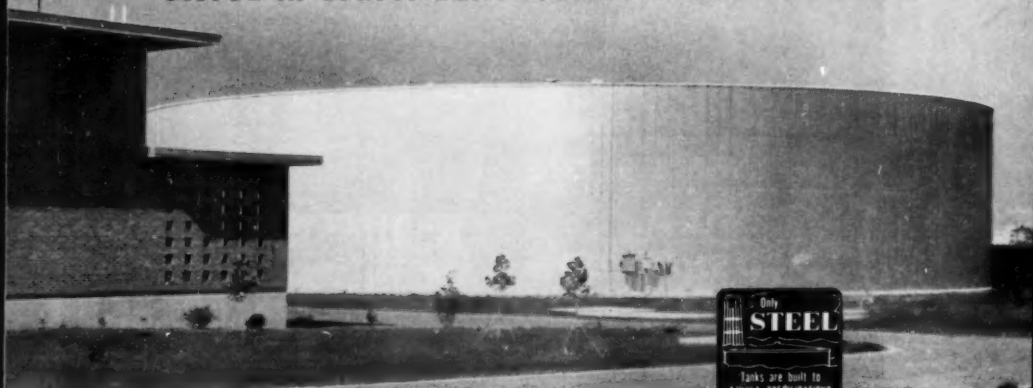
Feb. 20-24—Course on "Radionuclides in Water," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).

Feb. 27-Mar. 10—Course on "Water Quality Management—Sanitary Engineering Aspects," R. A. Taft Sanitary Engineering Center, Cincinnati, Ohio. Write: Chief, Training Program, 4676 Columbia Pkwy., Cincinnati 26, Ohio (or to USPHS regional office).



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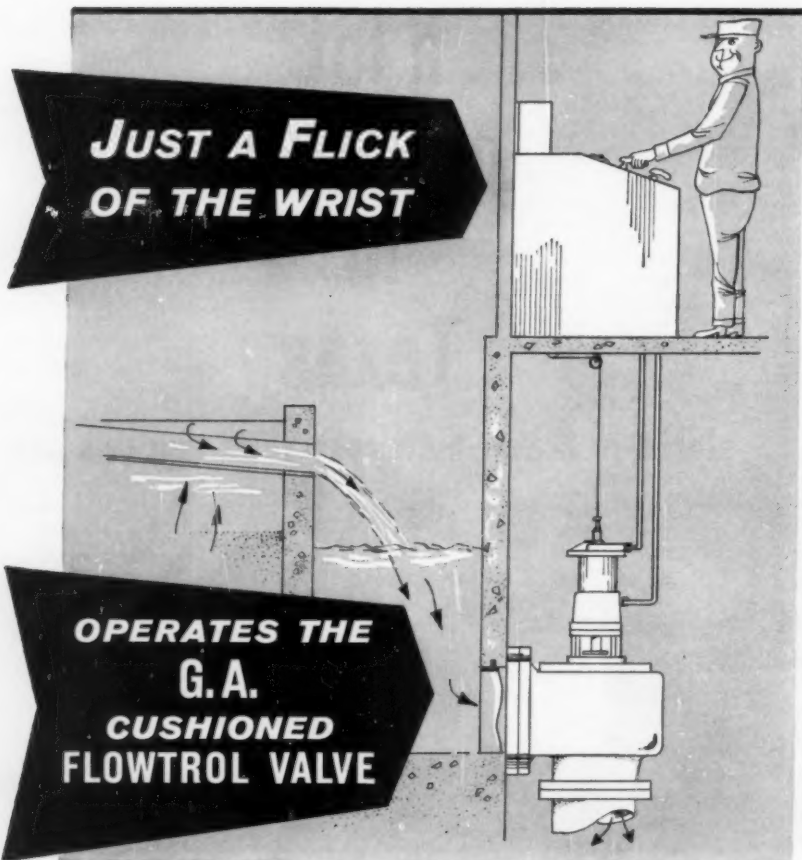
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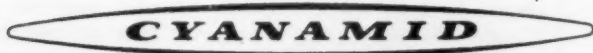
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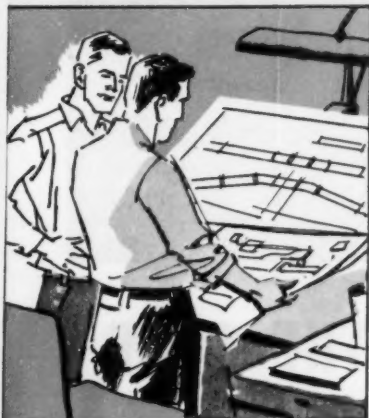
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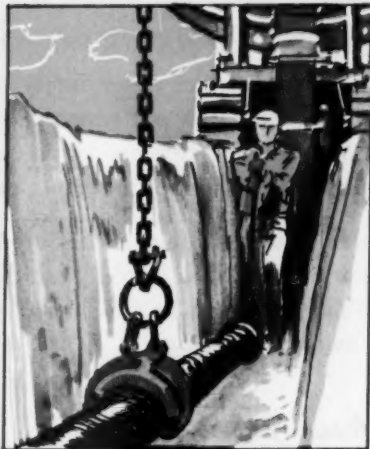


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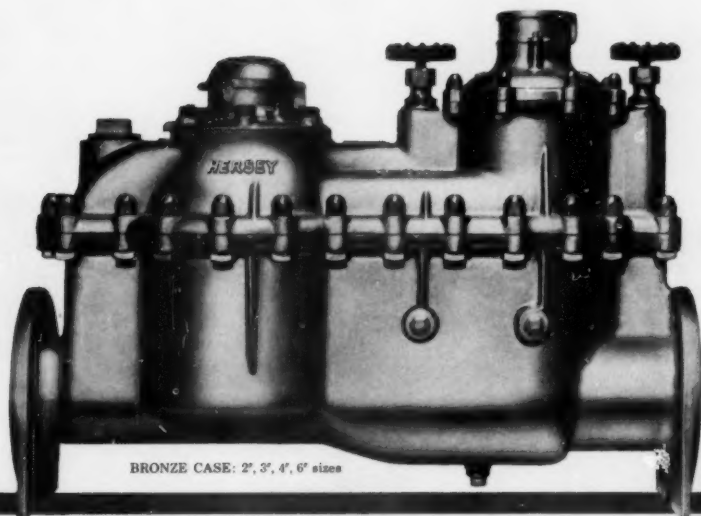
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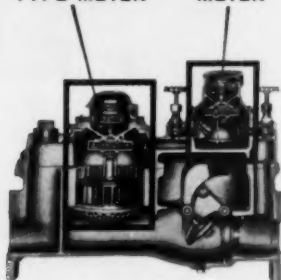
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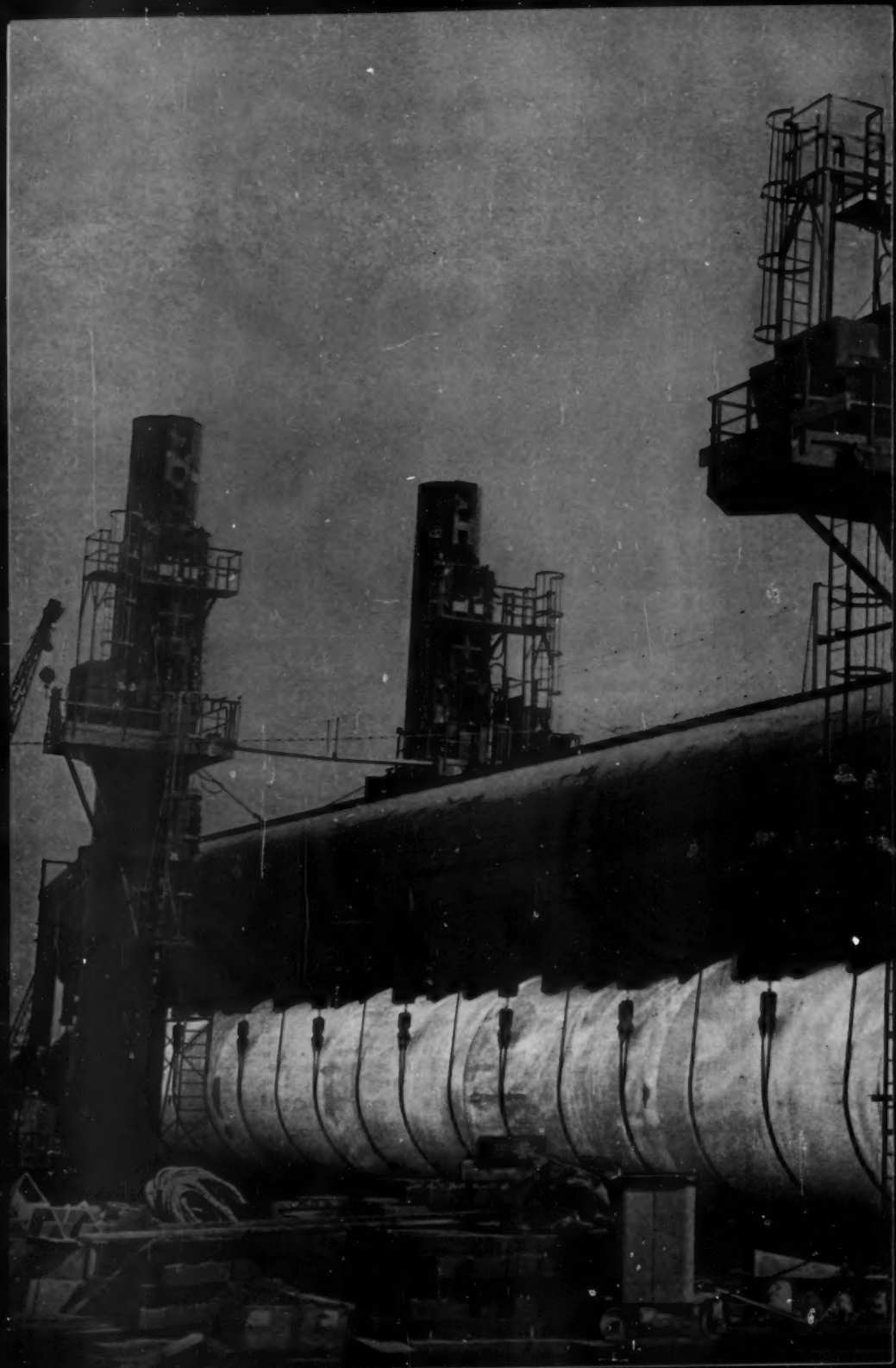
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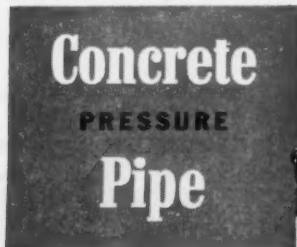
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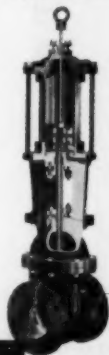
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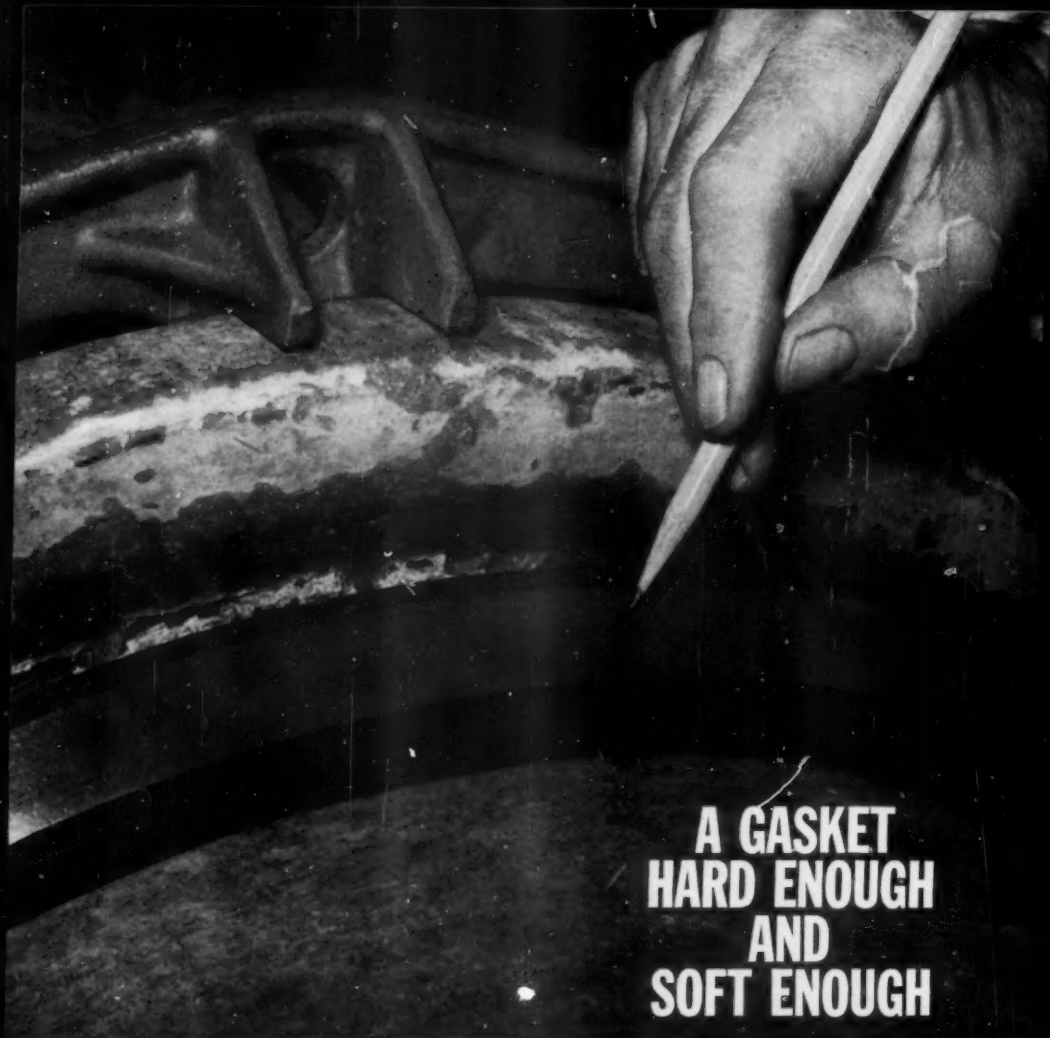
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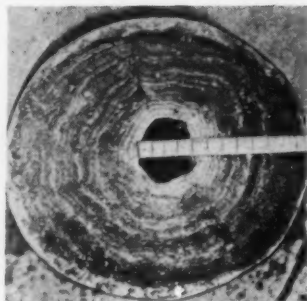


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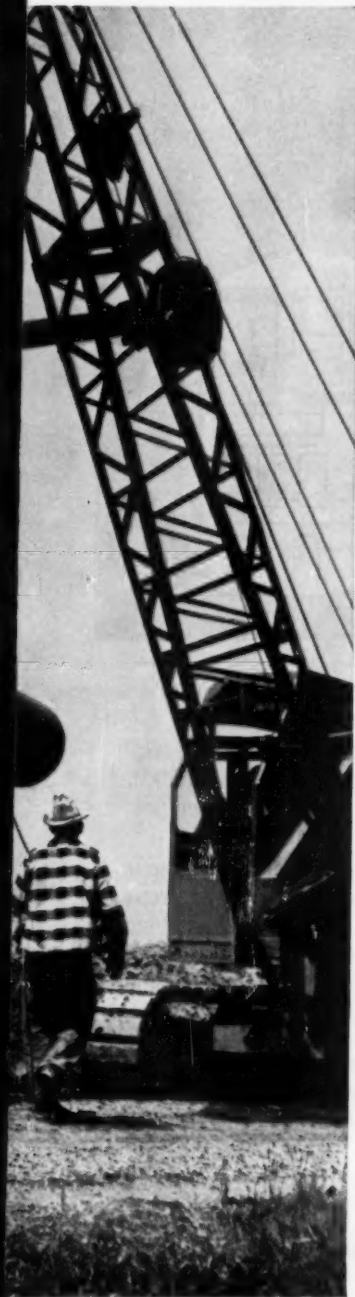
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# Journal

AMERICAN WATER WORKS ASSOCIATION

VOL. 53 • JANUARY 1961 • NO. 1

## Water Supply—A Continuing Challenge

C. F. Wertz

*A statement by C. F. Wertz, President, American Water Works Assn., and Director, Dept. of Water & Sewers, Miami, Fla.*

**A** YEAR ago Lauren Grayson, as president of AWWA, pointed to water supply as "America's Greatest Challenge."<sup>1</sup> It still is! And it promises to continue to be a tremendous challenge for many years to come.

In his statement, Lauren Grayson was referring primarily to the challenge posed by the fact that so many communities in this land of ours are deficient in water supply. He pointed out that this was due not to lack of water, but to lack of the facilities required to carry the water to the consumers—a deficiency, that is, in raw-water storage, in pumping, in transmission lines, in treatment, and in distribution facilities. There is still a deficiency in these respects, and that, too, promises to continue for some time. It will continue until water utilities do something about two very serious shortcomings:

1. Too many water utilities have failed to do any long-range planning. Thus, not only are they unable to provide for current needs, but they do not

even know what their future needs will be.

2. Too many water utilities have failed to acquaint their customers—the public—with the need to do something about these deficiencies and the need to take steps to provide for future growth of the community. Thus, when the bond issues to pay for even minimum requirements come up for a vote, the public cannot be expected to appreciate their importance.

It is the water utility, locally, that must solve this problem. It is AWWA's job to provide leadership. And it is the job of everyone connected with the field of public water supply to lend a hand in the effort. Only through combined effort can the challenge be met and only through meeting the challenge can the industry progress.

### Quality Water

But there are challenges other than just that of making up for past deficiencies. There is the challenge of

providing quality water service—that is, quality service of quality water. It is true, of course, that the industry is doing a tremendous job with the facilities that it has available at the present time. Through dedicated effort, water works men have assured the public of a safe water supply. Furthermore, the public has been sold on their ability to accomplish this task. Perhaps the public has even been oversold, for safe water is now taken too much for granted. Even so tragic a mistake as the recent waterborne typhoid epidemic at Keene, N.H., has not shaken the faith of the American people in their ability to drink without fear from any public water supply in the land.

This has been a tremendous accomplishment, of course, but if the industry is to grow, if the utility is to grow, and if the water works men involved are to grow, the provision of a safe water must be considered only a first step in providing quality water service. Too many water utilities are providing water that is turbid, colored, hard, corrosive, or in other ways falls short of the quality that they could provide. If the public is letting them get by with this kind of service, it is undoubtedly because the public has not been informed of how good a job the water utility can do these days in producing quality water. Industry is not so uninformed. And if a local water utility is providing an inferior product, chances are that the community, rather than getting by, is getting bypassed by industry seeking new plant sites.

### **Selling the Public**

Quality water will cost more money, of course, and the idea of increasing

production costs in the face of rate structures that are already inadequate may seem foolhardy. But the public has proved in many other fields that it will spend money to buy quality. And it should be easier to sell the public on spending more money for a softer, clearer, or better-tasting water than on paying more for the same old stuff. Furthermore, the difference in cost of providing quality water and providing merely adequate water service is really negligible.

The real cost will be in effort—in local research effort to determine how the supply can best be improved in quality and then in the sales effort of convincing the public that the improvement will be worth much more than its cost. As with the job of making up for past deficiencies, the most important effort will have to be made locally by the water utility itself. Again, AWWA has a responsibility for providing the leadership. And again, the industry as a whole has a responsibility for participating.

Toward the goal of providing quality water service, every new discovery of water supply research, every article or advertisement in the public press, every advancement in the understanding and ability of the water works man, every speech to, or even conversation with, the layman will mean a step forward. It will take many steps by many people to reach the goal. But if we are ever to get there, we must start now.

### **Reference**

1. GRAYSON, LAUREN W. Water Supply—America's Greatest Challenge. *Jour. AWWA*, 52:1 (Jan. 1960).

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## Evaluation of Available Supplies in the Western United States, in Relation to Desalinization

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—Samuel B. Morris—

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*A paper presented on May 5, 1960, at the Colloquium on the Desalting of Water, at the California Institute of Technology, Pasadena, Calif., by Samuel B. Morris, Cons. Engr., Los Angeles, Calif.*

**W**ESTERN United States refers to the seventeen states generally lying west of 100 deg longitude, with the exception of Alaska and Hawaii. This includes all of the desert and semiarid areas of the United States. It contains, also, along the Northern Pacific Coast ranges, the areas of most rainfall (more than 100 in.) and much of the high-mountain areas of the Cascade, Sierra Nevada, and Rocky Mountain ranges where rain is generally in excess of all vegetation requirements. Such areas are the principal sources of the streams and rivers of the West. With the exception of the Pacific Northwest, all areas in the West, including nearly all metropolitan areas of largest population and major industry and irrigated agricultural lands, lie principally in the regions where mean annual rainfall is low, varying from 5 to 20 in.

The seventeen western states make up 61.5 per cent of the area of the continental United States, not including Alaska, but average only 27 per cent of the runoff of 48 states. The western states include, however, in the Pacific Coast States and Arizona and Nevada, areas with the most rapid population and industrial growth in the nation, with the single exception of Florida. Nearly all irrigated agricultural lands are in the West.

Therefore, in the seventeen western states water supply and waste disposal problems are of truly major proportions. The area has the least rainfall and lowest runoff. The locations of irrigable lands, population, and industry—in relation to places with heavy rainfall and streamflow—are most displaced. There are vast areas of closed basins, such as the Imperial Valley of California and the Great Basin centering in Nevada and Utah. And, yet, in the western United States are the nation's largest dams, reservoirs, hydroelectric plants, longest aqueducts, and greatest per capita consumption of water.

### Developments in the West

One important favorable factor to be considered is that the West is a newly settled land. Many customs and mistakes of the older, more populous areas of the United States and of the Old World have not developed in the West. The population has the vitality, spirit, and optimism of youth. One finds such a bold proposal as the California Water Resources Development Bond Act for \$1,750,000,000 authorized at the last session of the state legislature and approved by the voters at the general election on Nov. 8, 1960.

The California project provides for more than 4,000,000 acre-ft per year—

3,500 mgd—to be stored and transported as far as 600 mi by a great multiple-purpose water project. Flood control, salinity control, hydroelectric power to lessen the cost of water deliveries and water for irrigation, municipal and industrial use, recreation, and fish and wildlife would all be included in this one great project. The major costs allocated to water use are to be fully returned to the state by those benefited in the north and south San Francisco Bay area, western and southern San Joaquin Valley, San Luis Obispo and Santa Barbara counties, and Southern California. Even if

River Aqueduct, built in 1905–13 and extended, in 1930–40, an additional 100 mi to Mono Basin; the 167-mi Hetch-Hetchy Project for San Francisco, built in 1913–34; the 100-mi Mokelumne Project for the East Bay Municipal Utility District, built in 1925–31; the 300-mi Colorado River Aqueduct of the Metropolitan Water District of Southern California, built in 1932–41; Denver's 32-mi tunnel through the Continental Divide; and many other notable municipal water supply projects.

In the fields of irrigation, flood control, and hydroelectric-power genera-

TABLE 1  
*Average Values for Runoff and Water Use in the United States, 1950*

Item	17 Western States*	31 Eastern States	Continental United States†
Area—1,000,000 acres	1,168	737	1,905
Runoff—1,000,000 acre-ft	393	1,057	1,450
Runoff depth—in.	4.03	17.23	9.13
Irrigated area—1,000,000 acres	22	‡	22
Water Use			
Municipal & industrial—1,000,000 acre-ft	10	80	90
Irrigation—1,000,000 acre-ft	90	‡	90
Total	100	80	180

\* In 1950, the population of the seventeen western states was 34,000,000.

† Excluding Alaska.

‡ Negligible.

fresh water from the sea were available for municipal use in Southern California, the use of this water would defeat the purposes of the project in the San Joaquin Valley, as irrigation would be uneconomical if municipalities did not pay a share of aqueduct costs. In 1990, when water in addition to that supplied by this project will be required, a new economic analysis can be made before a second state aqueduct is constructed.

The California state plan is the outgrowth of such great earlier works as the 240-mi Los Angeles-Owens

tion, great works of the West constructed by the United States are too numerous to mention more than a few major projects: Hoover Dam and the All-American Canal; Grand Coulee Dam and the Columbia Basin; Shasta and Friant dams of the California Central Valley Project; the Colorado River-Big Thompson Transcontinental Divide Project; the Glen Canyon-Upper Colorado River Storage Project; and the works of the Army Corps of Engineers and the Bureau of Reclamation on the Missouri River.



John Wesley Powell, who first navigated and explored the Colorado River and gave an intelligent analysis of the opportunity for man in the development of the West, had the vision that is still being realized and unfolded in the semiarid West. It was his ideas, enthusiasm, and work that led to the founding of USGS and the Reclamation Service, now the Bureau of Reclamation. The lake behind Glen Canyon Dam is to be named in his honor, as Davis Dam on the Colorado River was named in honor of his nephew, Arthur Powell Davis, an early director of the Reclamation Service.

The foregoing outstanding works and important events should help to show the imaginative and zealous manner in which the settlers of the West worked undaunted to capture water and bring it to lands and people. The vision and deeds of the pioneers of the West are succeeded by those in each new generation.

### Runoff and Water Use

The low average runoff in the semiarid West in comparison to that in the humid East is shown in Table 1. Runoff in the eastern states varies from 11 in. for the upper Mississippi to 24 in. in New England—an average total of 17 in. Runoff depths in major drainage areas of the West are shown in Table 2.

The data in Table 2 indicate that the three Pacific Coast states have more favorable runoff than do other states in the West; the other fourteen states may expect severe limitations on their full development, especially with regard to irrigation. But even in the three Pacific Coast States, a severe maldistribution of available water exists, both in time and location. There is insufficient water for full development in the Snake River Valley, east-

ern Oregon, in California generally south of Sacramento, and in the Great Basin and Colorado River drainage areas. Exhaustive studies have shown that there is sufficient water in California, including its Colorado River diversions, to meet fully the ultimate requirements of approximately 50,000,000 people and nearly 20,000,000 irrigated acres of land. The large storage facilities—surface and underground—the long aqueducts hundreds of miles in length, and the high-lift pumps needed to utilize this water will result in high costs.

The need for more and more water in the semiarid West (with the ex-

TABLE 2  
*Runoff in Major Drainage Areas  
of the West \**

Drainage Area	Runoff Depth in.
Great Basin	1.0
Colorado River	1.1
Missouri River-Hudson Bay	1.9
Rio Grande-Western Gulf	3.2
Arkansas-White-Red rivers	7.0
California-Pacific	12.0
Pacific Northwest	13.0

\* The average runoff depth in the seventeen western states was 4.03 in. (Table 1).

ception of favored locations in the Northwest and northern California) is recognized everywhere. Westerners have been conditioned to support large expenditures to construct works that will provide adequate water supplies. They have become accustomed to look to leading engineers to find the most economical solution to their future water supply needs. It is with this thought in mind that the discussion of desalinization is now pertinent.

### Feasibility of Desalinization

It is understandable that the ancient and persistent idea of practical pro-

duction of fresh water from the sea or from inland saline waters should gain impetus in the enthusiasm of the West. In further support is the inherent faith of westerners in the ability of modern science to find an answer, as it has so conspicuously done in finding the secrets of nature through research. An example of the results of the faith in, and support of, science in California is that nowhere in America is there such an aggregation of Nobel laureates in science as at the California Institute of Technology, the University of California, and Stanford University.

It would have been very simple for the author to have emphasized the semiarid nature of the West as compared to the humid East; that there is far more land than can ever be irrigated from the streams and ground water of this, on the whole, water-deficient area; and that the West has 1,500 mi of land facing the sea. The Office of Saline Water points out that there are 320,000,000 cu mi of sea water. For all practical purposes, the quantity is unlimited. There are also large amounts of inland saline waters; in fact, these are being contributed to all the time by return water from irrigated lands, and their quantity is increasing. Almost all the nation's saline waters, with the exception of tidal coastal saline waters and connate water at great depths, are to be found in the West.

The author then could have rested, satisfied that he had adequately set forth the great need for fresh water from salt and saline waters in the West, and that the West is prepared to await science's solution to this somewhat simple problem. Instead, an attempt will be made to point out and evaluate some of the major problems resulting from land elevation and remoteness from sea water and the difficulty in

disposing of wastes from inland extraction of fresh water from saline waters. These problems are so great and would necessitate such high costs that there seems to be relatively little major use for the production of fresh water supplies from the sea or from inland saline waters.

### **Cost Factors**

The need for water is not independent of cost, especially for irrigation use. If adequate high-quality water costs only \$1 per acre-foot, all semiarid lands of proper elevation, topography, and soil type will be irrigated when markets for their crops develop. If, however, irrigation water costs as much as \$20 per acre-foot (6.14 cents per 1,000 gal), then only favored lands and locations can grow and profit from such high-value crops as cotton, citrus fruits, nuts, and truck gardens. In general, municipal water users have been able to pay whatever the water costs. The cost and type of water use, however, become important factors in the location of an industry requiring a large quantity of water in relation to the market value of its products.

What are the needs for developing fresh water from the sea along the Pacific Coast of the United States? In the states of Washington and Oregon, there is a great surplus of excellent fresh water, making the use of converted sea water permanently unnecessary. The same situation is true of the California Coast north of Marin County in the San Francisco Bay area, where there are great surpluses of low-cost natural water. From there to San Diego on the Mexican border is an area where the comparable costs of water recovered from the sea and natural water transported in long aqueducts from the Sacramento-



San Joaquin Delta to water-deficient areas must be and have been reviewed.

Fortunately, California, since 1947, has been engaged in thorough studies of available water supplies, present and future water requirements, and the most economic means of conveying surplus waters from the north to meet the future supplemental water needs of the rest of the state. The studies clearly indicate that there is sufficient natural water, including contracts for Colorado River water, to meet all future water needs within the state. Large surface and ground water storage facilities and long aqueducts will be required.

As mentioned before, the California Water Resources Development Bond Act to authorize \$1,750,000,000 in bonds was approved at the general election held Nov. 8, 1960. The average cost of water delivered wholesale to Southern California is estimated to be \$50-\$70 per acre-foot. It is planned that the California project will meet the water needs of definite service areas that contract with the state from the north San Francisco Bay area to San Diego. Costs per acre-foot will be very much smaller for shorter distances and lesser pump lifts along the aqueduct. The cost at and above the Delta is estimated at only \$3.50 per acre-foot (1.075 cents per 1,000 gal).

As the major market for water in the West is for irrigation, and the magnitude of this market depends on the cost of water to the irrigator, it is necessary that some cost data be examined.

### Desalinization Costs

In a letter dated Jul. 13, 1959, to the Secretary of the Interior, directed to the attention of the director of the Office of Saline Water, Senator R. S.

Kerr, chairman of the Senate Select Committee, made a request with regard to a report on desalinization processes<sup>1</sup>:

The report should contain a brief description of desalinization processes now in use, both here and abroad, discussing engineering principles, costs per thousand gallons and per acre-foot, and environmental conditions, and actual areas within the United States suited to the application of these processes.

The letter asked for similar information on processes in the pilot plant stage, and the:

... best estimate of to what extent desalinization will be practiced by 1980, giving geographical areas and amounts of water that can be produced at various cost levels.

The reply, from the Assistant Secretary of the Interior, made on Oct. 19, 1959, stated (equivalent costs in acre-feet have been inserted by the author):

Just prior to World War II the cost of converting sea water to fresh ranged upward from \$4 per thousand gallons [\$1,304 per acre-foot]. In one or more of the plants that Public Law 85-833 authorized the Department to construct and operate, we expect to convert saline water to fresh for less than \$1 per thousand gallons [\$326 per acre-foot]. . . . New processes, still in the laboratory stage and not advanced far enough to be considered for demonstration plant programming, give promise of lowering the cost of conversion below 50 cents per thousand gallons [\$163 per acre-foot]. . . .

For years the citizens of Coalinga, Calif., like many other communities in this country, have had to haul in their drinking water supplies. In Coalinga, this water was obtained at a cost of \$7 per thousand gallons [\$2,282 per acre-foot]. Earlier this year this community cut their water bill to \$1.45 per thousand

gallons [\$473 per acre-foot] and made U.S. history by becoming the first to get its drinking water supply from brackish well water.

The committee report<sup>1</sup> also contains these cost data:

The cost of fresh water produced by the most efficient existing sea water conversion plants is now about \$1.75 per

### Costs in California

Although it is true that in rare instances, as in the inland oil town of Coalinga, a small supply from local saline water may be the present answer to the water supply problem in California, the high production cost of obtaining large quantities of fresh water from the sea cannot compete with the

TABLE 3  
*Estimated Costs of Producing Fresh Water From Inland Saline Waters  
by Use of Electrodialysis Process*

Type of Original Water	Saline Concentration of Original Water ppm	Saline Concentration of Product Water ppm	Total Initial Plant Cost \$	Costs—\$/1,000 gal					Total Costs \$/acre-ft
				Plant Investment	Operation & Maintenance		Total		
					Membrane Replacement	Power & Other			
Actual Field Experimental Unit (0.025 mgd)									
Arizona	4,000	250	63,000	0.54	0.47	0.29	0.76	1.30	425
South Dakota	2,000	250	59,400	0.50	0.37	0.23	0.60	1.10	360
Projected Intermediate Size Plant (1.5 mgd)*									
Arizona	4,000	500	1,650,000	0.23	0.30	0.27	0.57	0.80	260
South Dakota	2,000	500	1,310,000	0.18	0.23	0.19	0.42	0.60	197
Projected Large Plant (75 mgd)†									
Arizona	4,000	250	46,900,000	0.12	0.07	0.21	0.28	0.40	130
South Dakota	2,000	250	33,800,000	0.09	0.05	0.11	0.16	0.25	82

\* Based on multiples of present stack without design changes. Progress in design improvements will lower these costs. Costs are slightly higher for 250 ppm product.

† Based on possible future development of larger stacks and other technologic developments.

thousand gallons [\$570 per acre-foot]. It is anticipated that the first two sea water distillation demonstration plants will produce fresh water from the sea for \$1 or less per thousand gallons [\$326 per acre-foot].

Table 3, from the committee report, shows estimated costs of producing fresh water from inland saline waters by use of the electrodialysis process.

cost of long aqueducts. These aqueducts will deliver billions of gallons of water per day (millions of acre-feet per year). It should be pointed out that with the California multiple-purpose water program, the cost of the water at the Delta is only 1.075 cents per 1,000 gal (\$3.50 per acre-foot). For use in the San Joaquin Valley, fresh water from the sea would have to com-

pete with this cost. All other costs of the state's program are the costs of pumping and transmission, which would also have to be added to the cost of converting sea water.

Although retail costs of municipal water delivered through the customer's meter are generally 10-30 cents per 1,000 gal (\$32.60-\$97.80 per acre-foot), water production costs are generally 3.07-6.14 cents per 1,000 gal (\$10-\$20 per acre-foot) for local supplies, and 6.14-21.49 cents per 1,000 gal (\$20-\$70 per acre-foot) for present and planned water supplies conveyed hundreds of miles through large aqueducts. Costs of irrigation water delivered to the farmer's headgate are generally \$1-\$10 per acre-foot (0.307-3.07 cents per 1,000 gal) and may be as much as \$40 per acre-foot (12.28 cents per 1,000 gal) for limited areas of very high-value crops.

#### **Status of Other Western States**

Western states other than California, where opportunities may exist for the use of fresh water extracted from sea water along the Gulf Coast, should be considered. Louisiana may be dismissed, because it has access to large quantities of fresh water, except, possibly, for a small isolated community or industry.

Along the Texas coastline, the heavy rainfall of 50 in. at the more eastern rim decreases in the west and south, diminishing to about 25 in. at Brownsville. The coastal plain of Texas differs from that of the Pacific Coast. Texas has slowly rising lands continuing 100 mi or more inland from the Gulf. All along the Pacific Coast, the Coast Range Mountains parallel the coast, leaving only occasional plains or low, rolling hills for large populations, industry, and irrigated agriculture. The most extensive terrain of

this kind is occupied by the Los Angeles metropolitan area.

The total runoff of Texas rivers and streams is much less than that of California, and usable lands are several times more extensive. Accordingly, it is conceivable that there may come a time when Texas may have to use the sea as an additional source of fresh water. This is, of course, dependent on delivery of such water at prices that can be paid.

The inland areas of the seventeen western states have substantially all the saline waters of the country. In general, such waters do not exist in the Columbia River and coastal drainage areas of the Pacific Coast. They do exist throughout the Rocky Mountain States and are very extensive through the Great Plains, from the Dakotas to Texas. One of the problems of continued irrigation of lands is the necessity of washing the salts downward so they will not accumulate in the soil. This drainage is frequently a serious problem.

#### **Disposal of Waste Water**

A low-cost means of producing fresh water from inland saline waters may become of material benefit. But a careful analysis must be made of the effect of extensive fresh-water production on streams and ground water basins. In any process for the production of fresh water from saline waters, it is necessary to get rid of the concentrated saline water resulting from the extraction of fresh water. In all processes, there is no reduction in the total volume of salt; and in every process having a reasonable prospect of ultimate use, it is not dry salt that remains to be disposed of, but salt solutions of varying concentrations.

Presumably, recovery plants located at inland saline sinks—such as the

Salton Sea, the Great Salt Lake, and many lesser surface and ground water accumulations of saline water—would have no great difficulty in disposing of the more concentrated saline water. Through the passing of time, however, the available raw saline water would become more and more concentrated, adding to the costs of recovery of fresh water.

Many states have already encountered the problem of disposing of oil field brines, which are 5-95 per cent of the volume of oil extracted from the oil-bearing formations. The release of such brines, which may be much more concentrated than sea water, has severely polluted many inland streams and ground water basins. Frequently, the only remedy is to pump the waste brines from oil production back into porous rocks as deep as those from which the oil with water was initially extracted. This process is by no means inexpensive, although sometimes it has a compensating value when it increases the production of oil or gas.

An example of the high cost of pumping waste brines into deep underground rock formations where they will not contaminate useful fresh ground water or surface streams is given by these values: 8,948,763 barrels of brine were pumped underground at a cost of \$349,926.94, or 3.9 cents per barrel. This may not be a high cost in relation to oil at \$2-\$3 per barrel, but when the values are converted to a water cost of 93 cents per 1,000 gal (\$303 per acre-foot), it can be seen that a heavy financial burden is placed on any plant that has to dispose of its waste brine in this manner.

## Conclusions

It is not enough to point out the increasing demands on fresh water supplies and suggest that future shortages, when they occur, may be met by extracting fresh water from the sea and inland saline waters. Insofar as the United States mainland is concerned, it seems that there will be no substantial need or opportunity to use desalinization plants along the Pacific Coast. A need for these plants may develop along the Texas Gulf Coast when the lower-cost natural waters are fully utilized. Inland in the seventeen western states, there will develop a great need for additional sources of water. This is an area with substantial quantities of saline waters, where agriculture, especially irrigated agriculture, has a prominent or predominant role in the present economy of each state. As natural fresh waters become fully developed, it will be difficult for agriculture, because of costs, to compete with urban and industrial demands for water. Any solution to water problems involving the production of fresh water from saline waters will have to be within the price range of those who need the water for irrigation. It seems that the high costs of disposing waste saline water from desalinization plants may, in many instances, offer an added problem in the use of inland saline waters as a source of fresh water. Lower costs for methods of extracting fresh water from the sea and inland saline waters are definitely needed.

## Reference

1. Saline Water Conversion. Report of Senate Select Committee on National Water Resources, Washington, D.C., Com. Print 26 (1959).

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## Five Years of Experience With Desalinization at Morro Bay

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Albert W. Bruce

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*A paper presented on May 5, 1960, at the Colloquium on Desalting of Water, California Institute of Technology, Pasadena, Calif., by Albert W. Bruce, Supervising Mech. Engr., Pacific Gas & Electric Co., San Francisco, Calif.*

**F**IVE years of experience at the Pacific Gas & Electric Co.'s Morro Bay Power Plant, near scenic Morro Rock in San Luis Obispo County, Calif., has demonstrated that distilling fresh water from sea water is an effective method of providing a fresh water supply. Other sources of fresh water for the plant were investigated: the local municipal water supply and the wells on the plant property. The construction of a reservoir on a nearby creek was also considered. Use of the municipal system was eliminated because of the limited supply. It was thought possible that the wells might dry up or become contaminated with salt water. Use of sea water evaporators was preferred to construction of a reservoir, because the evaporators would yield a sure supply of fresh water at the lowest annual cost. The Morro Bay plant is the first land-based sea water evaporator plant in the United States. It proved its worth in the fall of 1959, when the local water supply failed for a short time.

Many developments of methods of obtaining fresh water from sea water have taken place in the past 7 years. In 1953, however, the only equipment that had been used long enough to demonstrate its reliability was the submerged-tube evaporator. A triple-

effect evaporator set was selected at Morro, because it was the most economical set that would fit in the available space at the plant. While studies were being made to select the type of fresh-water system to use, the "high-purity" station evaporator was procured. The vapor to be produced from it was selected as the steam supply to the sea water evaporator.

For the first two 165,000-kw generating units\* in the plant, it was determined that a 100-gpm fresh water supply was adequate for all purposes. Therefore, each of the two sea water evaporator sets was specified to produce 50 gpm of distillate with a water quality of 50 ppm dissolved solids. About half the distillate is required for boiler makeup and is redistilled in the station evaporator to a quality of 0.5 ppm or less of dissolved solids. This boiler makeup is the best in the system because of the low silica content in sea water. The remainder of the distillate is pumped to a 500,000-gal standpipe located on the bluff above the plant. This water, mixed with the water pumped from the wells on the property, is used for general

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\* The term "unit" refers to the generating unit and its auxiliary equipment, including the boiler and evaporator sets.

utility purposes. Figure 1 shows Evaporator Set 1 and its station evaporator.

### Service Experience

Experience in the past 5 years has shown that, on an annual basis, only

mallo operated for 1 week at a time and is then replaced by the other set.

Because of the arrangement of the station, for construction purposes it was desirable to build Unit 2 first. It went into operation on May 20, 1955; Unit 1 began operating on Mar. 27,

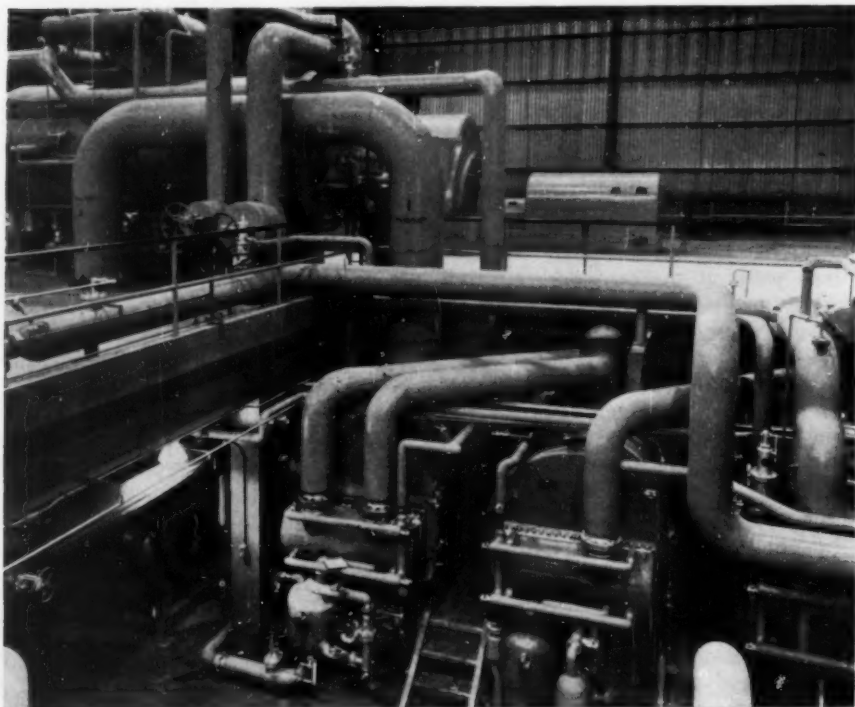


Fig. 1. Sea Water Evaporators

*Shown are the evaporators for the first unit, located below the operating floor of the plant. Above and to the left of the unit is its station evaporator.*

20-25 per cent of the capacity of the two evaporator sets has been required. The wells have been used to supply the additional quantity required for general utility purposes. This has not placed a great burden on the evaporator system; therefore, one set is nor-

1956. For greater reliability of makeup water, both sets of evaporator equipment were completed with Unit 2, and temporary piping was installed so that both sets could be operated with it. Evaporator Set 2 went into operation on Apr. 14, 1955; Set 1, on



Jul. 28, 1955. Since that time to Mar. 15, 1960, Set 1 has had more operating time—18,153 hr. Set 2 has operated for 16,557 hr. This makes a total of 34,710 hr for the two, compared with an elapsed time of 43,056 hr.

### Evaporator Cycle

Before the corrosion of the materials in the evaporators is discussed, the evaporator cycle and equipment should be described. As shown in Fig. 2, the steam for the submerged heating tubes of the first effect is supplied from the station evaporator, which is supplied from the fourth extraction point of the main turbine. The distilled vapor from the sea water in the first effect supplies the second-effect tubes; and, in turn, the second-effect vapor supplies the third-effect tubes. The vapor from the third effect is condensed in the evaporator-condenser, which is cooled by sea water. Part of this sea water, which is heated in the condenser, becomes the feed to the evaporators and cascades from the first-effect shell, to the second-effect shell, and then to the third-effect shell. It is then pumped from the third-effect shell to the main circulating-water outlet pipe. The sea water has about 36,000 ppm dissolved solids concentrated 1.5 times, or to 54,000 ppm, on discharge from the last effect.

The vacuum in the evaporator-condenser is maintained by a steam jet air ejector, whose condensers are cooled by the distillate from the evaporator-condenser. The condensate from the first-effect tubes is returned to the feedwater cycle by discharge to the main station condenser through a drain cooler that heats the sea water supply to the first effect. The distillate from the second-effect tubes is flashed in a

flash tank, the vapor going to the third-effect tubes and the water to the evaporator-condenser. The distillate from the latter is pumped through the air ejector condensing tubes, part of it feeding the station evaporator and the remainder going to the raw-water storage tank. Each evaporator effect is vented at the front and rear of the shell; the gases are evacuated to the evaporator-condenser. It is important that the oxygen and carbon dioxide be evacuated to reduce shell corrosion.

### Evaporator Set Materials

The shells of the sea water evaporators, 6 ft in diameter and 20 ft long, are made of  $\frac{3}{4}$ -in. welded copper-bearing steel. Each effect has 1,050 sq ft of 1-in. OD, 16-BWG \* aluminum-brass tubes, with naval rolled-brass tube sheets and cast-bronze floating head covers. On the first effect of Set 2 only, there are installed for experimental purposes tubes of 70-30 cupro-nickel inhibited with 0.5 per cent iron, and tube sheets of 90-10 cupro-nickel inhibited with 1.5 per cent iron. The tubes were installed with a 1.75-in. square pitch to aid in scale cleaning.

The evaporator-condenser shell is made of welded copper-bearing steel, and has a 40-in. OD and 15-ft 10-in. overall length. It has cast-iron water boxes and covers, and steel support plates and air baffles. A total of 1,150 sq ft of 0.75-in. 18-BWG aluminum-brass tubes are used with naval rolled-brass tube sheets. As with the evaporators for experimental purposes, Set 2 had tubes of 70-30 cupro-nickel inhibited with 0.5 per cent iron and

\* Birmingham Wire Gage defines the thickness of the tube.

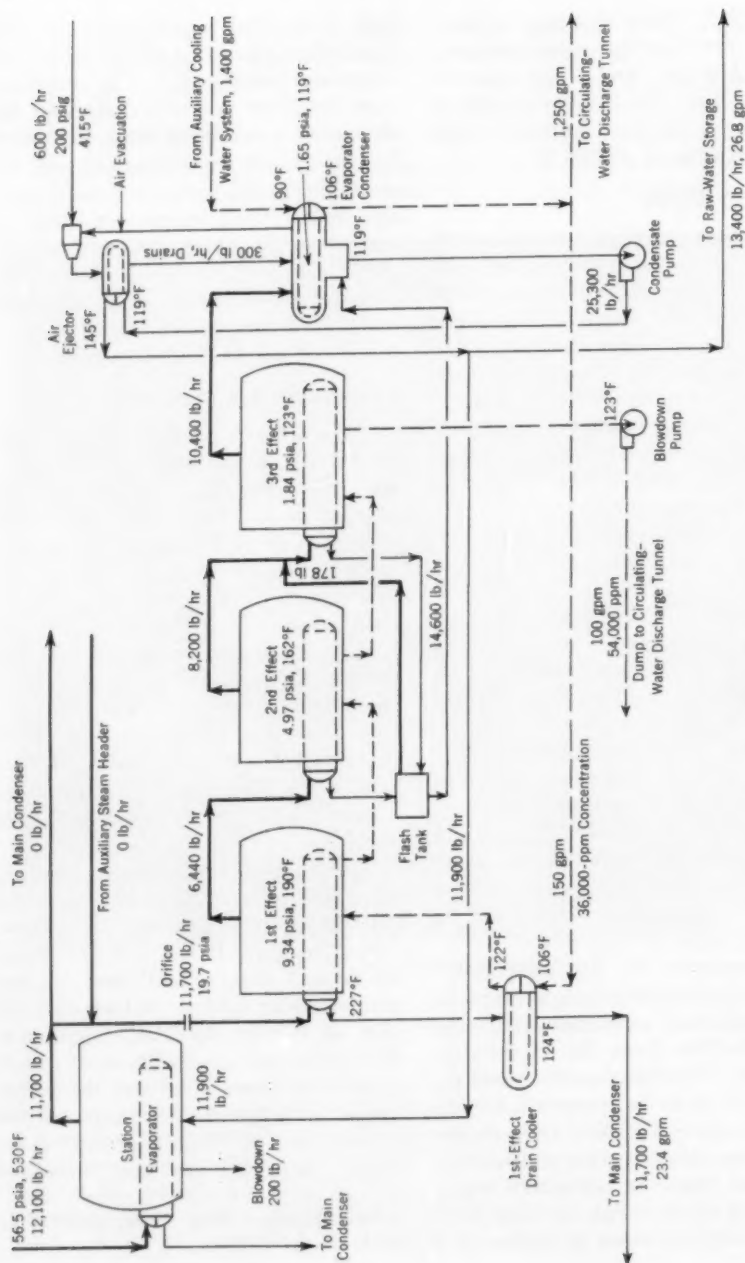


Fig. 2. Triple-Effect Evaporation

The heavy solid lines represent the path of steam; light solid lines, the path of fresh water; and dashed lines, the path of sea water.

naval brass support plates and air baffles.

The first-effect drain coolers have 0.365-in. walls, 10.75-in. OD seamless steel pipe with cast-iron channel, channel cover, and return cover, and aluminum-brass tubes. Set 2 has naval bronze channels, channel covers, and partition plates.

### Corrosion

*Evaporators.* After 5 years, there is no noticeable corrosion on the tubes or tube sheets of the first effect of either unit. It would therefore seem that the aluminum-brass tubes are adequate for this service, and that the more expensive cupro-nickel materials are not required. As would be expected, the lower-temperature second- and third-effect tubes and tube sheets are not corroded either.

The steel shells of all three effects of both sets show some corrosion above the water line. The corrosion is somewhat more pronounced in the center of the shells than toward the ends. The heaviest corrosion in all effects is occurring in the immediate vicinity of the inspection lights. This is believed to be the result of greater condensation, as the shell is not insulated at this point. The corrosion of the shells is most severe in the second effect, but it has not become severe enough to arouse concern for the safety of any of the shells. The corrosion of the sets is probably greater because of their intermittent service; rusting occurs when a set is not in service.

The carbon steel plates of the steam separators and the cracking lines in the steel of all effects are seriously corroded and will require partial replacement. It is planned to replace them with carbon steel, because this

material lasts for a reasonable length of time at minimum expense.

The shells of Set 2 were given a protective coating\*; Set 1 was left bare. The shell corrosion is greater on Set 1. It is planned to acid-clean the sets and coat the shells and other steel parts with protective coating.

*Evaporator-condenser.* There is no noticeable corrosion present on the steam side of either the aluminum-brass or 70-30 cupro-nickel tubes in the evaporator-condensers. In both instances, there was minor discoloration of the tubes directly under the shell-support stays, undoubtedly due to products of corrosion from the shell-support stays depositing on the tubes. Removal of these deposits produced a discolored but smooth tube.

The steel baffles and tube-support sheets of Set 1 contained a very minor amount of pitting, whereas the naval rolled brass in Set 2 was completely free of corrosion.

There was considerable corrosion of the evaporator-condenser shells in the area where the third-effect vapor line enters. Also the shell-support stays were corroded. The corrosion is probably bad at this point because of the condensation with oxygen and carbon dioxide. Corrosion is also found in the 24-in. OD crossover line, which takes the vapors from the third-effect evaporator to the evaporator-condenser. The corrosion in this line was of considerable concern in the first year of operation. Hoies were drilled in the pipe, and it was determined that the thickness was within the mill tolerance for the pipe. The corrosion appears not to have progressed much from that time. The line was insulated; this re-

\*Apexior 3, made by Dampney Co. of America, Boston, Mass.

duced condensation and is believed to have reduced corrosion.

### Feedwater Treatment

Experience with the operation of the evaporators at designed conditions of 19.7 psia, 228°F steam supply, and 190°F first-stage brine temperature indicates that tube cleanliness cannot be maintained for prolonged periods without some form of feedwater treatment. Operation also indicates that scale control is improved when the tube metal in contact with the brine is maintained at temperatures less than 190°F. This gives temperatures of 172°F in the sea water brine. The output is reduced to about 80 per cent under these conditions.

As it has not been necessary to operate at full capacity, feedwater treatment has been adopted for the reduced conditions. The treatment has consisted of various concentrations of starch\* containing a dispersing agent that eliminates the need for cooking the starch. In addition, an experimental study was made with the use of the British Admiralty treatment, which, although effective, was discarded because of its cost of about 35 cents per 1,000 gal of distillate.

The present treatment, which has been in use for more than 2 years, consists of a solution of starch and an antifoaming agent.† These chemicals are mixed with fresh water in the mixing tank and fed into the makeup line to the first-effect shell by means of a proportioning pump. The chemicals are fed in the ratio of 0.125 lb of starch and approximately 40–50 ml of

antifoam per 1,000 gal of distillate produced. The addition of the antifoam was found desirable, because certain pollution leads in the evaporator feedwater caused foaming with subsequent carryover. As a precautionary measure, the antifoam is added continuously with the starch, rather than when foaming occurs. The cost of the treatment is 2.5 cents per 1,000 gal of distillate.

### Chemical Cleaning of Evaporators

Evaporator Set 2 was cleaned once on Sep. 2, 1955, in the first year of operation, when it was necessary to load the evaporators heavily and they became badly scaled. Although, now, both sets can still meet the reduced demand, it is considered desirable to clean the evaporator chemically when evidence shows a possible loss of availability if sudden demands are made on the evaporator. It is proposed to clean Set 1 in the near future. The cost of the cleaning with inhibited hydrochloric acid is about \$1,500 per set.

### Comparison of Evaporator Systems

To compare methods of producing fresh water from sea water, it is necessary to estimate the total annual costs. Such costs are a combination of the annual fixed charges on capital, heat cost, costs for pumping, and operating and maintenance costs that give the least annual cost. The sea water evaporators for Units 1 and 2 have served well, but there are now available newer developments that should make the cost of fresh water less. A scheme has been studied for a 325,000-kw unit using a multistage flash-type evaporator. The flash-type evaporator would provide a high-quality distillate with less than 0.5 ppm dissolved solids from sea water containing 36,000 ppm

\* Nalco Starch D-1357, made by National Aluminate Corp., Chicago, Ill.

† Nalco 71NA, made by National Aluminate Corp., Chicago, Ill.

dissolved solids. This water will be suited to serve as makeup for a high-pressure boiler.

The steam supply for the evaporator set would come from the next to last extraction point on the turbine, with a pressure of 0 psig and a temperature of 212°F at maximum rating. This compares with Morro Bay Units 1 and 2, in which the steam supply from the station evaporator is from the fourth extraction point, with a pressure of 44.8 psig and a temperature of 530°F. The steam requirement for the unit studied is about one-third of the requirement for the Morro Bay submerged-tube evaporators.

It is estimated that the cost of fresh water from the present Morro Bay units, if they were operated at full capacity for the whole year, would be \$2.50 per 1,000 gal, when the fuel cost is 35 cents per 1,000,000 Btu (\$2.24 per barrel of 6,400,000 Btu fuel oil). For the flash-type evaporator studied, it is estimated that the cost of fresh water would be \$1.20 per 1,000 gal at 100 per cent capacity, with a fuel cost of 35 cents per 1,000,000 Btu. Obviously, for lesser amounts of fresh water produced, the unit cost of water is greater, but the annual cost is smaller.

If the sea water evaporation method had not been used, it would have been necessary to install a treatment plant to make other raw water a suitable makeup supply for the station evaporator. In addition, it would have been necessary to install an evaporator-condenser for condensing the steam from the station evaporator.

### Conclusions

The submerged-tube evaporator sets for Units 1 and 2 have demonstrated that they were effective for producing fresh water from sea water. The use of copper-bearing, carbon-steel-welded shells for the evaporator shells has been satisfactory, although there has been some corrosion. Scale control can be maintained at a small cost of 2.5 cents per 1,000 gal of fresh water. The total cost of fresh water at full capacity is estimated to be \$2.50 per 1,000 gal, with fuel costing 35 cents per 1,000,000 Btu. This cost can be reduced with newer types of sea water evaporators.

The use of sea water evaporators at the Morro Bay plant—the least costly method of producing a fresh water supply for the plant—demonstrates that it is possible to locate a plant on the seashore if the site is desirable but does not have fresh water.

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## Film-Speaker Public Relations Program at Los Angeles

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—John W. Baleria—

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*A contribution to the Journal by John W. Baleria, Public Relations Representative, Dept. of Water & Power, Los Angeles, Calif.*

**D**URING the last decade, the Los Angeles Department of Water and Power—servicing every home, business, and industry in a 458-sq mi area—has brought the important issues of its administration to the attention of audiences totaling more than 6,000,000 people. This was accomplished by the department's film-and-speaker program.

Because of the rapid population growth of Los Angeles and the increasing use of electricity by consumers, it has been necessary for the department to rush to completion additional steam-generating facilities. To convey this story of expansion and the need for it to the citizens of Los Angeles, a motion picture, "Power for Progress," was recently produced. The film tells the story of electric power in Los Angeles. When the showing of the film is followed by a qualified speaker's discussion of future plans for the power system, an outstanding program is the result.

### Organization of Program

In essence, the combination of films and speakers—presented before business, fraternal, educational, church, and civic organizations—serves as a valuable public relations tool of the department. A prime factor in the success of this extensive public information

program is its economical operation. Two factors contribute to this economy: (1) all aspects of the program are handled within the department, except for actual production of major films; (2) the attractiveness of the program draws large attendance, greatly reducing the cost per person reached.

The information program is presented and staffed by an internal speaker's group consisting of department personnel, including many from top-level management and from supervisory levels. Acting in the interests of public service, these personnel receive no special compensation for their speaking engagements. Coordination and administration of the extensive information service is accomplished by the department's Public Relations Division, which handles information services along with other duties.

Color motion picture film is used as the primary vehicle for communication. These films, many of them produced within the department, have raised attendance while reducing speaker preparation time.

The author believes that the best public relations are achieved through the person-to-person approach. The use of motion pictures gives the public relations man an opportunity to present his story directly to a great



many people. The cost of producing and showing motion pictures is very low per viewing guest.

### **Speakers Club**

The Speakers Club of the department was formed more than 25 years ago. Even at that time, during the depression, Los Angeles was expanding. Demands for increased water and power services were mounting.

The department, of course, could not expand without increased financial backing. Therefore, approximately twenty top-level executives of the Department of Water and Power formed the Speakers Club to tell the public the story of the department and the needs and problems of the future. Most of this story was told directly by the speakers. Occasionally, a 35-mm black-and-white film, which the department produced, was incorporated in the program.

Today, there are nearly 100 members in the Speakers Club. About twenty men are most active in presenting the program to the public. Other members help in the operation of the club—servicing equipment, compiling new facts, and keeping records—or are trainees for the program. All are considered to be available when an intensive campaign arises with its heavy demands for film showings and talks.

The speakers cover the entire Los Angeles metropolitan area, speaking and showing films to service clubs, civic organizations, and women's and other groups that want the facts about water and power. Whenever possible, a speaker will present the program to the organization for which he is best suited. For the most part, however, speaking engagements are determined by location. The speaker living near-

est to a meeting location will be given the assignment. The majority of these meetings are at night.

### **Operation of Program**

Approximately 40 meetings or film lendings per month are handled by the Public Relations Division, which has an excellent variety of color films to offer and which also provides for projection as needed. Engagements, for the most part, are in answer to requests from the clubs or groups. Occasionally, announcements will be mailed to many organizations that might be interested, informing them of new films or other available programs. Primarily, the personal contacts with the various organizations are more than enough to keep the program in demand. Requests for speakers and films may be handled by any of the three members of the Public Affairs Section.

A weekly calendar is maintained listing all the engagements, together with a listing of all members of the Speakers Club. This listing is color coded to show immediately: (1) the members currently available as speakers, (2) the members trained to operate a 16-mm projector or a 35-mm slide projector, (3) the organizations these men belong to or are familiar with, and (4) the sections of the city most convenient to members. With this weekly calendar and speaker information listing, the section is usually able to accept an engagement and provide the name of the speaker at the time of the initial request.

The department has found that it is advantageous in the great majority of the engagements to show a motion picture film. Films have a strong drawing capacity and result in excellent audience attention and retention.

Although films will be loaned on request, the Public Relations Division prefers to assign an accompanying speaker, because films alone cannot always answer all the questions that arise. Also, the development of the department is so rapid that new material cannot be provided through film coverage alone. The speakers, then, act as the interpreters of up-to-date developments.

Although this number of school children represents the major portion of the total audience of 6,670,000 people reached in the last 10 years, the majority of programs were conducted for adults. Between 1949 and 1959, approximately 50,000 service organization programs were provided.

Not all the films pertain strictly to the past, present, and future applications of water and power. For such



**Fig. 1. Filming of Water Department Motion Picture**

*Cameras roll on a studio set as the narrator prepares to dub in the sound track.*

### **Scope of Program**

Of all films loaned, the majority go to schools. It is estimated that within the last 10 years nearly 5,000,000 children have seen films on water and power provided by the department. In many instances, classes doing projects on water conservation have utilized these films in their work.

groups as sportsmen's clubs or Boy Scouts, entertaining films will be provided showing recreational facilities in areas from which water and power resources initiate.

### **Production and Types of Films**

Initially, the department produced its own films, but now finds it preferable to have its major films prepared by

established firms (Fig. 1). All productions today are in 16-mm sound-and-color films. Most schools and organizations are equipped with 16-mm projectors; a few, with 35-mm projectors. The department finds it much easier to instruct personnel in the use of 16-mm projectors.

In the production of new films, or in the remaking of old films, the department has found that the 24-25-min film

There are about ten films that the department uses in the majority of its engagements (Fig. 2). Two of these are 14-min sports films. The remainder are historical, dramatic, or informative films on water and power. These films run, on an average, about 25 min.

Often, however, requests will come to the department for programs for which no films are available. For



**Fig. 2. Section of Owens Valley Aqueduct System**

*Shown is a section of concrete line of the Los Angeles Owen Valley Aqueduct system that extends approximately 340 mi north along the eastern slope of the High Sierra. Several motion pictures made by the Los Angeles Department of Water and Power recount the story of the aqueduct and its service to residents of Los Angeles.*

represents an ideal length to fit most of its requirements. Many organizations want a 30-min program. A 25-min film fits into this time allotment and allows the speaker to make a brief talk. Films of 25-min duration are also well adapted for television screening.

example, a technical school may desire a program about the construction of special underground power transmission lines. In these instances, the department will locate a film covering the desired subject. If requests for a particular film subject are numerous, the department may consider purchasing

one of two prints from a concern that has produced such a film.

The department has many motion pictures available besides "Power for Progress." Among these are:

1. "The Twin Titans," a film of historic interest about how water and power have made possible the building of Los Angeles in a semi-arid locale

2. "California Waterama," a documented film about water problems threatening California's growth

3. "Hoover Dam," an official film of the Bureau of Reclamation presenting the history of the dam

4. "Pipeline to the Clouds," a film about the water cycle which answers many questions about problems of water supply.

### Conclusions

The actual cost of conducting the public information program is determined, to a considerable degree, by the amount of film produced or purchased. This factor is controlled, however, by the ability of well-informed speakers to extend the subjects beyond the contents of the films.

With the economical use of motion picture films and competent speakers, the Los Angeles department is keeping its citizens up to date on department projects and is enhancing its public relations. In doing this, the department is creating additional understanding and support to assist its progress in the future.



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## Status of Water Supply in Connecticut

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—Warren J. Scott—

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*A paper presented on Oct. 6, 1960, at the Connecticut Section Meeting, Hamden, Conn., by Warren J. Scott, Director, San. Eng. Div., State Dept. of Health, Hartford, Conn.*

THE first public water supply in Connecticut was developed in Durham in 1798. After 1850, the number of public water supplies increased rapidly. The state now has 145 systems supplying water to 25 or more households each, or an estimated population of approximately 2,101,000, which is 84 per cent of the state's population. In addition, 4,000 people in Pawcatuck are supplied with water from the Westerly, R.I., system and 40,000 persons in Port Chester, N.Y., and Rye, N.Y., are supplied by the Greenwich Water Co.

### System Development

Of Connecticut's 145 systems, 27 are municipally owned and 118 are privately owned; some of the district and municipally operated systems, such as in Hartford, Waterbury, and New Britain, are among the largest. Hartford is the only metropolitan district which serves a number of towns. Some large privately owned utilities, such as the New Haven Water Co. and the Bridgeport Hydraulic Co., serve a number of towns. The Connecticut Water Co. has several divisions in separated communities. Another operates the Noroton Water Co., the Mystic Valley Water Co., and the Greenwich Water Co. Two other outside operating companies have acquired control of five systems.

Aside from the trend toward operating-company control of several systems, owned in some cases by persons within the state and in others by out-of-state persons, an important trend in the last decade has been the development of small realty subdivisions in previously sparsely populated areas. The growing tendency, stimulated by results of poor experience with private wells and private subsurface sewage disposal systems in close proximity, has been to install central wells for developments rather than private wells on individual lots. Most of these supplies are obtained from deep drilled wells; a few have been developed from relatively shallow gravel-packed wells. Although these central wells are undoubtedly safer than many private wells in relatively thickly populated areas, problems arise as to their management and proper local and state supervision. It is unfortunate that existing public water systems cannot be extended in many suburban locations to keep pace with the speed of building, but planning and financing to date have, in numerous instances, not made this possible. As the properties are built up, real estate developers frequently make plans for turning over their central water supplies to local associations of property owners.

The question is often asked whether better operating results are obtained

under municipal or private ownership. There are many arguments that may be advanced for either, and from the author's observation, there are good and poor examples of both. Certainly the water system is not something that should be made a political football. The placement and continued employment of competent personnel, and preferably the creation of continuing boards or commissions with charter provisions for overlapping terms of memberships, are needed to maintain good operating results and to develop essential long-range plans as to sources and distribution.

Also, privately owned utilities should recognize their responsibility to the residents in their service area and plan programs that insure the development of needed water supply sources to meet future demands in dry years and to provide water of satisfactory quality. Many of the privately owned utilities in Connecticut have done splendid jobs of future water supply planning. Bold plans and foresight are necessary because of the time that often must elapse between the conception of water supply projects and their completion.

### **Sources of Supply**

Of the 145 public water systems, 37 obtain water from surface sources, 76 from ground water sources, and 32 from a combination of the two. It is estimated that more than 90 per cent of the population served by public water supply systems consume water obtained from surface sources. In very recent years, important large additions to surface sources have been constructed in New Haven and Hartford.

Connecticut's natural surface water supplies are, in general, low in turbidity and suspended solids, so that the

problems of coagulation, sedimentation, and filtration have not been as great as in many parts of the country. The state department of health reports that turbidities of unfiltered water supplies do not range above 10. Of course, under extraordinary flood conditions such as occurred in 1955, turbidities on some streams may temporarily become excessive.

Average color of unfiltered surface water supplies in the state generally meets the standards of USPHS. In some locations, however, especially where a watershed contains considerable vegetation, with the occasional presence of high iron, the average color of unfiltered water may exceed 20 and sometimes will rise to 50 or more.

### **Chlorination Practice**

The first chlorinator installations on public water supplies in Connecticut were made in Stamford and Torrington in about 1912. By 1923—about the time that the Connecticut State Department of Health began to develop more extended supervision of public water supplies—the number of chlorination plants had risen to 50. From then on, the increase was rapid owing to increased interest in improvements by water utilities in general, as well as to growing evidence of disease protection from water treatment and constant stimulation by the department of health. The number of chlorination plants on public water supplies has now risen to 190. All surface water supplies in the state are now chlorinated and many well supplies are also protected by disinfection. The recognition of the potential danger from interruption of chlorination has led to many progressive steps by water utilities including the installation of standby chlorinating machines, provi-



sion of spare parts, residual recorders, automatic controls, standby power, and frequent testing for residual chlorine where no automatic recorders are used.

### **Filtration Practice**

Filtration plant installations have proceeded somewhat slowly in Connecticut because of the tendency to rely on clean watersheds which receive no sewage discharges and the relatively good physical and chemical characteristics of the natural water. Filtration is now needed on several surface supplies, however. The first sand filters were installed in Greenwich in 1888 and in Farmington in 1892. There now are 27 water filtration plants, including some on fairly large supplies such as Hartford, New Britain, Norwalk, Greenwich, Danbury and Groton. All plants are of the rapid sand type except for five older slow sand filter plants. It seems probable that rapid sand filters will be preferred in future installations.

Just as there has been a rapid increase in chlorination plants in the last three or four decades, it is probable that as the public becomes increasingly conscious of the poor physical quality of water represented by high color or objectionable tastes and odors, there will be a trend toward more filtration facilities on many surface supplies in the next two or three decades. Filtration with coagulation and sedimentation has many advantages, such as control of color and turbidity, reduction of odors and taste, elimination of trouble from distribution system infestations, anticorrosion treatment, control of iron and manganese, and, above all, provision of an extra safety factor in the removal of bacteria. Filtration adds substantially to the cost of water production because construc-

tion and operating expenses are considerable. But many communities in Connecticut and elsewhere are absorbing the cost of filtration without undue difficulty.

In these days of concern with protection of supplies from radioactive fallout, the question arises as to possible removal of radioactivity in water by filtration or other means. Many utilities have acquired equipment and have trained personnel to make periodic tests to obtain background information on radioactivity in their supplies. There is always some slight radioactivity present due to natural causes. Coagulation and settling are not particularly effective in removal of radionuclides except insofar as they are associated with suspended matter in the water. Sand filters are not effective in removal of radioactive materials except for particulate matter. Generally speaking, conventional water treatment processes will be ineffective in removal of radioactivity, although ion-exchange is effective. Ground water supplies from wells are likely to remain safe from radioactivity for considerable periods of time.

There has been some interest in microstraining installations to handle specific problems, such as elimination of worms (fly larvae) entering distribution systems. Recently there has been some consideration of diatomaceous earth filters for public water supplies, although for municipal supplies their benefits are limited.

### **Fluoridation**

Fluoridation of public water supplies in Connecticut has been actively promoted by those interested in protection against dental decay. The first installation was made at the Southbury Training School in 1945. It was fol-

lowed by those at New Britain and the Mansfield Training School in 1950; the Cromwell Fire District in 1951; the Mystic Valley Water Co. in 1953; the Torrington Water Co., the New Canaan Water Co., and the city of Willimantic in 1958; and the Metropolitan District of Hartford and the city of Bristol in 1960. In one or two other communities installations may soon be put in operation.

### **Softening**

In Connecticut, waters are generally soft, and there are no water softening plants on public systems except on a few very small well supplies; the same is true of iron removal plants. Anti-corrosion treatment with such chemicals as lime, soda ash and sodium hexametaphosphate is being used increasingly to protect against pipe corrosion and improve the physical quality of delivered water.

### **Cross-Connection Control**

The greatest step in elimination and control of cross connections between public water systems and unapproved water supplies used for industrial or auxiliary fire fighting purposes was taken by the Connecticut State Department of Health in 1926 when a sanitary code regulation was enacted by the Public Health Council. This new regulation prohibited the installation of cross connections after Dec. 31, 1926. Where there were existing installations including two gate valves with indicator posts, two check valves of a design approved by the state department of health with drip cocks and gages for testing, all located in a watertight vault readily accessible for periodic inspection, the date of discontinuance could be temporarily extended with the permission of the state depart-

ment of health. For about a year, the water utilities and the sanitary engineers of the department of health worked intensively with the full cooperation of industry and brought about the elimination of thousands of cross connections. Such cross connections had been the cause of serious outbreaks of waterborne disease in some sections of the country. The number of double check valves installations has now been reduced to 132. These installations are inspected and tested three times yearly by an inspector from the state department of health and yearly reports of opening, inspection, and cleaning of valves are submitted to the state department of health by the owners. The results of this supervision have been gratifying. No cases of simultaneous leakage of both valves have been found. No new cross connections with unapproved water supplies are permitted.

### **Waterborne Disease**

Although early reports of former state boards of health make frequent reference to waterborne typhoid fever, the first complete report of an extensive waterborne typhoid fever outbreak in Connecticut was made in 1901. It occurred in the city of New Haven. Evidence seemed to point conclusively to contamination of the Lake Dawson supply by excreta from a typhoid patient which were thrown on the ground. The epidemic resulted in 105 deaths and probably totaled 1,000 cases. At that time the supply was untreated and probably no systematic program of watershed inspection was carried out.

According to the records, the last Connecticut typhoid epidemic associated with a contaminated public water supply occurred in 1911, when 35

deaths from typhoid fever in Torrington were apparently traceable to infection of the public water supply by excreta on the watershed. Since that time extensive watershed purchase and improvements, together with chlorination, have eliminated the problem. If the 1900 typhoid death rate prevailed today, with the state's present population of approximately 2,500,000, there would have been 765 deaths in the state during the last calendar year, whereas there have been no deaths in the past 10 years. Even as late as 1915, there were 981 typhoid cases in Connecticut, and, with allowances for the increases in population since that time, such a case rate would mean 1,962 typhoid cases in the past year. The total typhoid cases in the past 5 years were: 1955, 11; 1956, 12; 1957, 2; 1958, 6; and 1959, 5. Safer water supplies, safer food and milk supplies, improved sanitation, and better personal hygiene have been largely responsible for the saving of lives and reduced illness. The occurrence of a waterborne typhoid outbreak from contamination of an unchlorinated surface water supply in Keene, N.H., in the fall of 1959, brings to mind the dangers that still lurk when proper safeguards are not provided.

### **Nature of Watersheds**

Connecticut is fortunate that its surface water supplies are obtained from watersheds where there are no sewage discharges into the water. Most of the watersheds are in rural areas, and on some of them there are no dwellings whatsoever. Sometimes this is due to utility ownership of the land or to a lack of access to the area caused by the absence of roads.

It is estimated that there are 1,000 dwellings on an area of 21.6 sq mi

on one large watershed in Fairfield County with an estimated population density of 200 persons per square mile. Most of the residents are commuters and their families. Comprehensive watershed inspections by the water utility with less frequent inspections by the state department of health are undoubtedly responsible for keeping sewage out of the streams.

There are no public sewerage systems on any watershed at present where the water is used for a public supply, with the exception of Lake Whitney, a source of water supply in the New Haven metropolitan area. Sewage collected in sewerage systems on the Lake Whitney watershed is drained to a point off the watershed. This watershed is considerably different in character from others that are used for public supply in the state. The lake drains a thickly populated area in the town of Hamden and a relatively densely populated section of Cheshire. No raw sewage or sewage effluent discharges into any source of public water supply in the state of Connecticut.

The Connecticut water utilities have done an excellent job in working with the state department of health on watershed sanitation. Occupied properties are numbered and mapped and continuous records are kept of watershed conditions. Corrective measures are instituted to abate nuisances where found.

### **Recreational Use of Watersheds**

Over the years there has been pressure from various groups to open public watersheds to widespread recreational use. Picnicking, boating, bathing, and fishing have all been the subject of proposed laws. Boating and fishing may be permitted on a local

basis on a reservoir under the control of a water utility. Fishing is prohibited in most downstream reservoirs although it is allowed under permit in a few. Fishing is permitted on many tributary streams, and, in fact, some tributary streams are artificially stocked for fishing. The decision to leave this matter to local supervision appears wise because of the varying conditions. Bathing in water supply watersheds was prohibited until 1959, when the legislature enacted a law to permit bathing in streams and ponds at points more than 2 mi above an upstream storage reservoir, except that the operation of bathing facilities for profit is not permitted. Bathing in downstream distribution reservoirs and their immediate watersheds is still prohibited.

Recreational use of watersheds poses a potential threat to the safety of the water, as has been learned by experience with many abuses by persons practicing recreational uses under permit. Certainly changes in the law should not be made hastily. Due consideration must be given the character of the watershed, the available storage, the populations involved, the adequacy of patrol, and the extent of water treatment. Some proposed recreation laws have provided that all public surface water supplies must be filtered. This may be desirable, but it is costly, and the degree of compulsion that can be applied must be considered.

### **Ground Water**

Many small communities in Connecticut and numerous housing developments are supplied with water from drilled wells in rock formations. The yield of individual wells on these supplies usually varies from 20 to 50 gpm,

a few wells yielding larger quantities. Gravel-packed wells located in favorable gravel formations have been developed to yield much larger volumes of water and successful wells have yielded 100–500 gpm, and a few wells deliver yields as high as 1,000 gpm. Unfortunately, conditions are not favorable for gravel wells in many locations. This type of well must be located in relatively coarse gravel formations to permit the withdrawal of large volumes of water. The draft that can be permitted on gravel wells close to the shore is limited because heavy drawdown of the fresh-water table may pull in salt water. The underlying gravel deposits in Connecticut may have important possibilities as sources of public water supply, however. A notable instance of large-scale ground water development is the gravel-packed well supply of the Bridgeport Hydraulic Co. in the valley of the Housatonic River.

The underground movement of detergents has adversely affected the quality of some Connecticut wells. Although no specific distance between wells and waste disposal systems furnishes a complete guarantee of protection, it is essential that reasonable acquisition of property be obtained in close proximity to public wells on which there may be considerable pumpage. A minimum radial distance of 200 ft has been set by the state department of health, but greater distances should be sought.

It is estimated that 118,000 persons, or 5.6 per cent of the total number of persons served by public systems in Connecticut, secure water from ground water sources. About 80 per cent of this ground water on public systems is obtained from gravel-packed, driven, or caisson wells.

## Resources Development

A state law provides that each petition for authority to develop or introduce any system of public water supply shall be accompanied by a copy of the recommendation and advice of the state department of health. This permits the state department of health to assist the legislature by offering advice on allocation of needed water. In this connection, the state department of health has constantly worked with local water utilities in developing studies of water supply adequacy.

For the purpose of estimates, it is frequently assumed that a flow of not greater than 50,000 gpd per square mile of watershed can be depended on without storage, even though it is true that some streams may dry up completely during a period of severe drought. Yield studies have indicated that it is usually advantageous to develop storage, where possible, up to a ratio of 100,000,000 gal/sq mi, and a substantial additional yield is produced by development of storage up to 200,000,000 gal/sq mi. As the storage ratio is increased beyond 250,000,000 gal/sq mi in New England, the proportion of safe yield becomes much less, and beyond 300,000,000 gal/sq mi little additional yield results. By provision of sufficient storage it may be possible to develop a safe yield of from 750,000 to 800,000 gpd/sq mi. Studies of safe yields are made on the basis of careful records on a number of New England watersheds, and USGS and some Connecticut utilities are adding to stream-flow records from gaging stations in the state.

By action of the legislature a special water resources commission was appointed to make a report on water resources to the 1957 Connecticut Gen-

eral Assembly. In the report submitted by this commission advantage was taken of the studies of the state department of health and many of the larger water utilities.

For the purpose of consideration of the water supply needs in various parts of the state, the state was divided in the report into eight areas: southwestern; south central; southeastern; northeastern; north central; Waterbury-Litchfield area; Danbury-New Milford area; and northwestern. In the report it was estimated that the state would have a population of approximately 3,500,000 in the year 2000 as against the 1960 population of 2,500,000.

It is of some interest to note that the water supplies that may be developed appear to be sufficient to satisfy the state until the year 2000 without drawing from large rivers. These rivers drain the watersheds of thickly populated communities and receive their sewage discharges. The state's sewage discharges are 94 per cent treated and there should in a few years be 100 per cent treatment. Sewage treatment, of course, is always subject to possible breakdown and relatively uncontaminated sources are greatly to be preferred.

In north central Connecticut, the cost of distribution may be expensive even though sources are adequate if water is piped a sufficient distance. The Danbury-New Milford area might develop shortages in present and contemplated sources if population growth is rapid. Extension of metering to eliminate undue waste of water would be helpful in prolonging water adequacies in this area. Projected plans and possibilities in other parts of the state look favorable, from the stand-

point of water supply adequacy for the next 40 years.

The future may see increased direct use of water from the larger rivers. Such supplies will have to be filtered as well as chlorinated and pollution by sewage and industrial wastes will have to be kept under the best possible control. Because of possibilities of interruption of treatment safeguards, these supplies will not be as safe as the unpolluted surface waters now being used. No immediate demand for their use now exists, although the rivers will continue to be useful for many kinds of industrial process water.

Much research is being undertaken on the conversion of salt water to fresh water. Great progress has been made in developing methods of conversion, and costs as low as below \$1 per 1,000 gallons seem possible. This cost, of course, does not include distribution. Costs must be lowered further to make converted saline water a serious competitor with present fresh-water supplies.

### **Conclusion**

Connecticut to date has a record of freedom from waterborne disease of which it can be proud. Water officials can continue to maintain this record only by sustained vigilance, close supervision, and constant planning for additional safeguards where possible. The natural surface and ground water supply sources in the state are free from sewage pollution. Treatment by chlorination and filtration provides

safeguards against the danger of chance contamination, which always exists.

The natural water supplies of Connecticut are generally soft and of reasonably good physical quality. A considerable number of filtration plants is now in operation in the state. Filtration will be provided to an increasing extent to improve water of poor physical quality. Such treatment will also furnish an additional barrier against waterborne disease.

Some further development of surface sources in clean watersheds can and should be made in the future, where possible. It does not appear necessary for several decades to contemplate obtaining supplies from large rivers, but the time may come and efforts in pollution abatement on these rivers should continue. Studies of ground water potential for water supplies in the state should be undertaken on a greatly expanded basis, and unquestionably a cooperative survey of ground water resources by the state and USGS should be planned over the next decade.

The people of Connecticut can well pay tribute to the courage and vision of many outstanding engineers and managers who have, in the past, developed long-range plans to assure adequate and safe public water supplies for the future. It is to be hoped that the next few decades will produce an equally good record in disease prevention and water supply planning. The state has a great stake in the development of its water resources.



# 1958 Inventory of Water Supply Facilities in United States Communities With Populations of 25,000 or More

**Kenneth H. Jenkins**

*A contribution to the Journal by Kenneth H. Jenkins, Statistician,  
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**A**LISTING of water supply facilities in the large cities of the United States, reflecting conditions as of Jan. 1, 1958, was issued by USPHS in April 1959. This listing continued the series of inventories begun in 1954, repeated for 1955 and 1956,<sup>1-4</sup> and scheduled to be issued every 2 years. A statistical summary of the data for each of these earlier years has been reported.<sup>5-7</sup> This report contains the national summary for 1958 and is directly comparable to that for 1956.

The present summary includes data for United States territories and possessions. Alaska and Hawaii are included in this category because they became states after 1958. Future inventories for the United States as a whole will be comparable with inventories made in 1956 and later.

## Analytic Concepts

The data for 1958 were summarized by punch card machine tabulation, and, as was announced in the 1956 summary,<sup>7</sup> the mutually exclusive concepts of "community" and "facility" are used.

A *community* is defined as a political or geographic entity having a water supply to which a census population may be assigned. It is a water-using entity and may be served by one or

more water-producing facilities. A community, as used here, is almost always an incorporated community as listed by the US Census Bureau.

A *facility* is a water-producing entity serving one or more communities.

TABLE 1  
*Analysis of Supply Served to Communities  
of 25,000 or More*

Supply	Communities	
	Number	Percentage of Total
Source		
Surface	334	58.5
Ground	124	21.7
Surface & ground	113	19.8
Condition		
Treated	552	96.6
Untreated	10	1.8
Treated & untreated	9	1.6
Ownership		
Public	462	85.1*
Private	78	14.4*
Public & private	3	0.5*
Not stated	28	

\* Percentage of total of those communities for which ownership information was given.

TABLE 2  
*Facilities and Population Served in Communities of 25,000 or More*

Source and Treatment Status of Water Provided	Facilities		Population Served	
	Number	Percentage of Total	Estimated Number	Percentage of Total
Surface	393	60.0	68,475,090	75.9
Ground	211	32.2	13,935,144	15.5
Surface & ground	51	7.8	7,776,685	8.6
<i>Total</i>	655	100.0	90,186,919	100.0
Treated	635	96.9	89,118,900	98.8
Untreated	20	3.1	1,068,019	1.2
Treated & untreated	0	0	0	0
<i>Total</i>	655	100.0	90,186,919	100.0

TABLE 3  
*Facilities and Population Served in Communities of 25,000 or More, According to Source and Treatment of Supply*

Source	Number of Facilities	Percentage of Total	Estimated Population Served	Percentage of Total
<i>All Facilities</i>				
Surface	393	60.0	68,475,090	75.9
Ground	211	32.2	13,935,144	15.5
Surface & ground	51	7.8	7,776,685	8.6
<i>Total</i>	655	100.0	90,186,919	100.0
<i>Facilities Supplying Untreated Water</i>				
Surface	0	0	0	0
Ground	20	3.1	1,068,019	1.2
Surface & ground	0	0	0	0
<i>Total</i>	20	3.1	1,068,019	1.2
<i>Facilities Supplying Treated Water</i>				
Surface	393	60.0	68,475,090	75.9
Ground	191	29.1	12,867,125	14.3
Surface & ground	51	7.8	7,776,685	8.6
<i>Total</i>	635	96.9	89,118,900	98.8

TABLE 4  
*Services and Meters in Communities of 25,000 or More,  
 According to Ownership of Facilities\**

Ownership	Estimated Population Served	Number of Services	Number of Meters	Persons per Service	Percentage of Services Metered
Public	58,872,344	14,103,513	12,205,183	4.2	86.5
Private	9,122,425	2,540,246	2,266,487	3.6	89.2
Not stated	54,400	18,220	18,198	3.0	99.9
<i>Total</i>	68,049,169	16,661,979	14,489,868	4.1	87.0

\* Based on reports in which all data were available.

Where treatment is involved, the terms "facility" and "plant" are used interchangeably.

The use of these two concepts permits a more sound analysis of the data than is possible otherwise. Many communities receive water from both ground and surface sources, but the percentage of population served by ground sources—at least in the larger communities—is small. By using the "facility" concept, much of the population receiving mixed (ground and surface) water can be assigned to either ground or surface sources. The same situation exists with regard to communities receiving both treated and untreated water, although this point is of small consequence when supplies of the larger communities are considered. The use of these two concepts also permits comparisons to be made of the percentage of communities within each population group served by organized community water supplies. Although not important to the present study, this comparison is extremely relevant to summaries of small community practices which are now being made for all communities in the United States having a population of 100 or more. The use of the community type of analysis has another advantage in that it permits realistic com-

parisons between census populations and estimated populations served. The 1958 data are, of course, somewhat removed from the last decennial census, but the census data were used for grouping purposes. It is anticipated that by the time the 1960 water supply data are ready for summarization (late 1960), the 1960 census figures will be available.

### Analysis

It should be pointed out that included in the present summary are 42

TABLE 5  
*Metering and Facilities in Communities  
 of 25,000 or More*

Percentage of Services Metered	Facilities	
	Number	Percentage of Total
0	2	0.4
1-10	13	2.6
10-20	13	2.6
20-30	6	1.2
30-40	6	1.2
40-50	3	0.6
50-60	6	1.2
60-70	3	0.6
70-80	6	1.2
80-90	27	5.3
90-99	109	21.6
100	311	61.5

communities that do not strictly fit into the category of "25,000 or more." These 42 communities either have nearly 25,000 people or are places with fewer than 25,000 people but which serve more than 25,000. Altogether there are more than 1,500,000 people served in these 42 places.

Although not shown here, the data were summarized by population groups according to the 1950 census, by state, and for the first time, by major drainage basins.\* Advantage has been

and hydrologically. This permits interrelated tabulations of data on water supply and waste disposal facilities, as well as contracts awarded for the construction of such facilities and sales of bonds for the financing thereof.

This report presents only national summary data and is limited to various items concerning source and treatment, metering, certain treatment details, and reported needs. Data relating to water consumption and per capita use are being prepared for a separate presenta-

TABLE 6  
*Functional Classification of Plants Serving Communities of 25,000 or More*

Plant Classification	Plants		Population Served	
	Number	Percentage of Total	Estimated Number	Percentage of Total
Purification	270	42.5	40,731,460	45.7
Purification and softening	52	8.2	9,684,110	10.9
Purification and iron and manganese removal	9	1.4	499,000	0.6
Purification, softening, and iron and manganese removal	11	1.7	1,430,000	1.6
Softening	17	2.7	1,462,140	1.6
Iron and manganese removal	27	4.3	2,091,850	2.4
Softening and iron and manganese removal	12	1.9	1,001,510	1.1
Disinfection only	131	20.6	10,157,530	11.4
Disinfection plus another process	96	15.1	21,076,290	23.6
Miscellaneous	10	1.6	985,010	1.1
<i>Total</i>	635	100.0	89,118,900	100.0

taken of the master location system of the USPHS Basic Data Branch, whereby every named population center in the United States has been given a number that locates it geographically

\*A complete set of tables arranged by population groups, states, and major drainage basins is available to interested persons on request from the Chief, Basic Data Branch, Division of Water Supply & Pollution Control, Public Health Service, US Department of Health, Education and Welfare, Washington 25, D.C.

tion that will analyze changes that have occurred between 1948 and 1960. In the summary data, none of the figures on estimated population served has been rounded off, because of inherent difficulties in adjusting several sets of comparable data simultaneously. No fictitious precision is implied in these data, however; they are, at best, only estimates.

Table 1 shows the number of communities served, according to source of

water, treatment practices, and ownership of the facilities. The three communities listed as having both publicly and privately owned facilities are Rochester, N.Y.; Camden, N.J.; and Pittsburgh, Pa. These places have more than one facility, one of which is a privately owned water company.

Table 2 shows data on the number of facilities and population served. The 655 facilities served an estimated 90,000,000 people in 571 communities. This is an increase of more than 5,000,000 over the number of people reported in the 1956 inventory. The population served as reported in the

as shown in Table 3. All surface waters are treated.

Of the 543 communities reporting on ownership of facilities, 462 have publicly owned systems, 78 have privately owned systems, and 3, as mentioned before, have both publicly and privately owned systems (Table 1). Data on meters and number of services are shown in Tables 4 and 5. As might be expected, the percentage of services that are metered is higher for the privately owned systems. Information on meters was reported for 78 per cent of the facilities, for which 87 per cent of the services were metered.

TABLE 7

*Disinfectants Used in Plants Supplying Communities of 25,000 or More*

Disinfecting Agent	Plants		Population Served	
	Number	Percentage of Total	Estimated Number	Percentage of Total
Liquid chlorine	425	68.3	55,383,065	63.2
Chlorine and ammonia	136	21.9	24,399,390	27.9
Hypochlorites	14	2.2	473,285	0.5
Liquid chlorine and hypochlorites	15	2.4	3,445,840	3.9
All others	32	5.2	3,898,270	4.5
<i>Total</i>	622	100.0	87,599,850	100.0

1958 inventory was 36.0 per cent more than the 1950 census of the same places. The 1956 population served was 29.8 per cent greater than the 1950 census.

Of all the people served, 75.9 per cent received surface water, 15.5 per cent received ground water, and the remaining 8.6 per cent received both surface and ground water. Slightly more than 1,000,000 of these people received untreated water. They comprise only 1.2 per cent of the total. All the people using untreated water are served by ground water facilities,

Slightly more than 83 per cent of the facilities were more than 90 per cent metered. This is 0.6 per cent less than in 1956, but it is interesting to note a shift of 2.4 per cent of facilities from the 90-99 per cent metered group to those that are 100 per cent metered. Data on metering are widely diversified, as shown in Table 5. The relationship, if any, existing between metering and consumption will be explored in the forthcoming analysis of consumption.

A functional classification of the 635 plants is shown in Table 6. The mutu-

ally exclusive classifications shown are standard inventory classifications: purification, iron and manganese removal, softening, or any combination of these. Purification, used either separately or in combination with some other major plant function, connotes the presence of slow or rapid sand filters. Disinfection is used as a classification if none of the three standard classifications appears. The miscellaneous classification includes only those plants that fit none of the other classifications—plants that have separately, or in combination, aeration, sedimentation, chemical dosage, or corrosion control.

TABLE 8  
*Treatment Processes in Plants Serving  
Communities of 25,000 or More*

Process	Number of Plants	Estimated Population Served
<i>Filtration</i>		
Rapid sand (gravity)	316	47,835,760
Rapid sand (pressure)	19	2,712,970
Slow sand	23	5,752,875
Anthracite	45	5,208,330
<i>Aeration</i>	154	12,242,585
<i>Softening</i>		
Lime soda	43	6,235,350
Lime	36	6,052,150
Cation exchange	12	1,295,260
<i>Taste and Odor Control</i>	226*	34,294,615
Activated carbon	182	28,060,625
Chlorine dioxide	37	5,586,130
Others and not stated	38	6,637,760
<i>Corrosion Control</i>	236*	32,924,240
Phosphate compounds	95	9,502,270
Alkali for pH adjustment	161	24,781,475
Chlorine gas	11	792,960
Sodium silicate	4	622,500

\* Figures entered under "Taste and Odor Control" and "Corrosion Control" are not additive, because more than one chemical may be used.

TABLE 9  
*Chemicals Used for Coagulation or Softening in  
Plants Serving Communities of  
25,000 or More*

Chemical	Number of Facilities*	Estimated Population Served†
Alum	316	46,630,355
Lime	262	37,472,950
Soda ash	68	9,247,890
Iron salts	42	10,975,900
Activated silica	28	6,316,610
Others	30	3,346,510

\* Total number of facilities: 366.

† Total estimated population: 52,066,265.

Of the total of 635 plants, more than half employed purification as a prime plant function. The largest percentage of plants and the largest percentage of population served relate to purification as the sole function—42.5 per cent and 45.7 per cent, respectively (Table 6). Although these percentages have not increased much as compared to 1956 values, the slight increase represents twelve additional plants and 4,000,000 additional people. Disinfection, either alone or in combination with some other unit process, was the classification for 35.7 per cent of the plants serving 35.0 per cent of the population surveyed.

Nearly 88,000,000 people received disinfected water from 622 plants, as shown in Table 7. This is 98.3 per cent of the population receiving treated water and 97.1 per cent of all persons included in the inventory. More than two-thirds of the plants use liquid chlorine only; these serve 63.2 per cent of those receiving disinfected water. Chlorine and ammonia used together were reported for a lesser number of plants than in 1956, but the percentage of population served by



water disinfected in this way increased from 26.5 per cent to 27.9 per cent.

Summary data on various other unit processes in water treatment are given in Table 8. Gravity rapid sand filters were used in 316 plants serving more than 5,000,000 people. Taste and odor control measures were taken in 226 plants. Activated carbon, the most widely used vehicle, is employed in 182 plants serving 28,000,000 people. Some type of corrosion control was used in 236 plants serving

to indicate any of eight categories of improvements needed. Of the 655 facilities included in the inventory, 490 gave a definite answer. Of this number, only 97, or 19.7 per cent, indicated that their present facilities, serving nearly 11,000,000 people, were entirely adequate and that no improvements were needed. The remaining 393 reporting facilities, serving more than 57,000,000 people, indicated that there were a total of 1,119 improvements needed.

TABLE 10  
*Improvements Needed by Facilities Serving Communities of 25,000 or More*

Improvement Needed	Facilities		Population Served	
	Number	Percentage of Total	Estimated Number	Percentage of Total
Source, underground	81	16.5	8,118,445	11.8
Source, surface	97	19.7	13,594,735	19.8
Transmission	147	30.0	24,024,185	35.1
Pumping	134	27.3	22,934,020	33.5
Treatment	167	34.0	32,118,230	47.0
Distribution	225	45.9	31,288,350	45.7
Elevated storage	169	34.4	21,665,415	31.7
Ground storage	99	20.2	12,100,850	17.7
None	97	19.7	10,794,980	15.7
Total reporting	490	74.8	68,334,320	75.8
Not reporting	165	25.2	21,852,599	24.2
<i>Total</i>	655	100.0	90,186,919	100.0

33,000,000 people, and aeration in 154 plants serving 12,000,000 people.

Table 9 presents data on chemicals used for coagulation or softening in 366 plants using these processes. Alum and lime were the two chemicals most frequently used, being employed in 316 and 262 plants, respectively.

### Improvements Needed

On the inventory report form, space was provided for the reporting facility

Table 10 shows the improvements needed and the population served by the reporting facilities. It will be noted that more than 45 per cent of the facilities and the population served were in need of expanded distribution systems. Half were in need of expanded storage capacity, and a third were in need of water source development.

Caution should be used in interpreting these figures, because the reports

showed only the type, not the extent, of improvement needed. Nevertheless, the total population served has been related to each need. This gives some idea of the magnitude of the problem in water systems of larger cities, especially because fewer than one in five facilities indicated no need for improvements.

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## Survey of Meter Purchase, Test, and Repair Practices

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Robert C. Sisco

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*A contribution to the Journal by Robert C. Sisco, Production Control Supervisor, East Bay Municipal Utility Dist., Oakland, Calif.*

THE maintenance, periodic testing, and repair of water meters have received considerable attention over the years. There is, however, a noticeable lack of consistency in meter maintenance practices within the industry. In studies of practices at the East Bay Municipal Utility District, Calif., it was found that most procedures had been evolved over the years through experience and had never been carefully evaluated from an economic standpoint.

To help in the planning for more efficient operations, a questionnaire was prepared on maintenance practices for  $\frac{3}{4}$ -in. meters and circulated to 83 public and private agencies retailing water directly to the consumer. Kuranz<sup>1,2</sup> has made surveys of this type in the past covering essentially the meter repair phases of this survey. The data developed in this survey, however, differ to some extent from those reported by Kuranz.

Responses were received from 52 utilities, which represented more than 4,600,000 meters. The sample is not large enough, perhaps, to be truly representative of meter maintenance practices throughout the United States and Canada, but it should be adequate to permit the drawing of some reasonable conclusions. The sample was deliberately stratified to make it more rep-

resentative. Responses were received from water utilities with the numbers of meters indicated in Table 1.

The questionnaire divided meter practices into five categories: (1) cleaning, (2) repair, (3) testing, (4) purchase, and (5) replacement. The data on each of the five categories are presented below:

### Cleaning Practices

The first question covered cleaning methods used when meters are overhauled. Of the 52 respondents, only five (less than 10 per cent) used chemical means to clean meter exteriors. Most of the respondents (78 per cent) used physical means such as sandblasting, wire brushing, or steel grit. Six (12 per cent) did not clean the exteriors at all.

Of particular interest were cleaning practices for the interiors of meters. Acid cleaners were used by 58 per cent of the utilities, whereas 35 per cent

TABLE 1  
*Size Distribution of Questionnaire Respondents*

Meters in Service	Number of Utilities
Not reported	4
Less than 20,000	9
20,000-99,999	19
100,000-199,999	16
More than 200,000	4

did not clean the interiors except for a rinse with clear water. The remainder used either soap and water or an alkali cleaner. One comment received expresses the opinion of many concerning chemical cleaners:

We believe it is not good policy to remove corrosion from meter measuring chambers and gear trains if it does not interfere with normal meter operation. We believe that any metal-brightening process which might be used on meter interiors invites renewed—and, in most cases, more vigorous—corrosion.

The literature is replete with comments to the effect that variations in water quality make it impractical to standardize meter maintenance practices. As part of the survey, information was requested on the average analysis of the water served. An attempt was then made to relate the cleaning of measuring chambers and meter parts to the quality of the water served. Table 2 illustrates the fact that there is no direct correlation between water quality and the need to use acid for cleaning purposes—if it is assumed that all respondents are getting satisfactory results from their present method of cleaning.

TABLE 2

*Use of Acid Cleaning as a Function of Water Quality*

Chemical Characteristic	Acid Cleaning Used	Acid Cleaning Not Used
Calcium—ppm	2.3–62.5	8.0–105.0
Chloride—ppm	1.9–81.0	0.5–49.0
Dissolved solids—ppm	25.0–760.0	21.0–510.0
Hardness—ppm	8.8–250.0	4.3–338.0
Iron—ppm	0.01–0.47	0.00–0.60
pH	7.0–9.5	6.4–9.5
Sulfate—ppm	0.9–199.0	2.0–250.0

### Repair Practices

Practically all respondents rebuild dials (89 per cent) and intermediate gear trains (93 per cent), whereas only 70 per cent repair measuring chambers and discs. There did not appear to be any correlation between the meter repair practices followed and either water quality or the number of meters installed in the system.

### Tests

Most of the 51 utilities responding to the section on tests (84 per cent) test new meters. They do, however, use many different flow rates for test-

TABLE 3

*Utilities Using Various Test Rates for New  $\frac{1}{2}$ -in. Meters*

Test Rates gpm	No. of Utilities	Test Rates gpm	No. of Utilities	Test Rates gpm	No. of Utilities
20, 15, 10, 2	1	20, 10, $\frac{1}{4}$	1	20, $\frac{1}{2}$	1
20, 15, 8, $\frac{1}{4}$	1	20, 4, $\frac{1}{4}$	1	20, $\frac{1}{4}$	1
20, 15, 2, $\frac{1}{2}$	1	20, 2, $\frac{1}{4}$	4	18, $\frac{1}{4}$	1
20, 10, 2, $\frac{1}{4}$	2	15, 2, $\frac{1}{4}$ *	5	15, $\frac{1}{2}$	1
15, 10, 2, $\frac{1}{4}$	1	15, $1\frac{1}{2}$ , $\frac{1}{4}$	1	10, 1	1
15, $7\frac{1}{2}$ , 1, $\frac{1}{4}$	1	12, 2, $\frac{1}{4}$	2	10, $\frac{1}{4}$	3
11, 2, 1, $\frac{1}{4}$	1	12, 1, $\frac{1}{2}$	1	2, $\frac{1}{4}$	1
10, 2, $\frac{1}{4}$ , $\frac{1}{2}$	1	10, 2, $\frac{1}{4}$	5	2	1
20, 15, $\frac{1}{4}$	1	10, 1, $\frac{1}{4}$	3		
20, 10, 2	1	8, 3, $\frac{1}{4}$	1		

\* Recommended by AWWA.

ing new  $\frac{5}{8}$ -in. meters. Table 3 illustrates the variability reported.

The test rates for new  $\frac{5}{8}$ -in. meters recommended by AWWA<sup>3</sup> are 15, 2, and  $\frac{1}{4}$  gpm, but only five out of 45 companies test at these rates. Fifteen other utilities do, however, require acceptable test rates, the variation from those recommended by AWWA being only minor.

The practice of testing all meters received is still followed by 34 (79 per cent) of the companies testing new meters. Eight companies do not test new meters. The other nine respondents test lesser quantities of the meters received: 2, 25 per cent; 5, 10 per cent; 2, 5 per cent. Although the smaller utilities predominate among the nontesters, two of them do have more than 100,000  $\frac{5}{8}$ -in. meters in service.

The accuracies required at the test rates used are evenly divided between  $\pm 1\frac{1}{2}$  per cent (the AWWA requirement) and  $\pm 2$  per cent. Only 35 per cent of the utilities answering have meter accuracy standards set by law. An interesting point here is that 72 per cent of the accuracy standards set by law are  $\pm 2$  per cent, which is less restrictive than the AWWA standard is.

In most cases, less than 1 per cent of the new meters received fail to meet the required accuracy, and only one utility experiences as much as 3 per cent failures with a requirement of  $\pm 1\frac{1}{2}$  per cent.

### Purchase Specifications

Thirty-five per cent of the respondents require test certification from their meter suppliers, and 54 per cent require compliance with AWWA C700.<sup>4</sup> The other 46 per cent write

their own specifications, which, in many cases, are similar to C700, with additions.

From an economic standpoint it would seem reasonable to use the vendors' test certification to supplement a sampling inspection plan to reduce the amount of testing necessary. Instead, meter purchasers appear to be hyper-cautious toward test certifications. Of the 35 respondents that test all new  $\frac{5}{8}$ -in. meters, 24 require no vendor's certification; of the 17 respondents that test 0-25 per cent of new meters, 10 require no such certification.

TABLE 4  
*Meter Replacement Periods in  
Survey Sample*

Replacement Period years	No. of Utilities	No. of Meters in Group
5	2	66,000
8	16	1,180,000
10	12	1,500,000
15	3	200,000
20	1	117,000
25	1	150,000
30	2	271,000
35	1	60,000

### Replacements

Most of the companies covered (81 per cent) have a meter replacement program, but only 21 per cent of these are required by law. Of the 42 companies with meter replacement programs, 38 (or 91 per cent) base their replacement on time, generally 8-10 years. Naturally, all respondents replace broken or stuck meters when they are discovered, irrespective of age or use. Table 4 illustrates the distribution of meter replacement periods for the 38 utilities over the time range of 5-35 years.

### Conclusions

The most obvious conclusion that can be drawn from the survey is that meter overhaul and testing practice is still an art rather than a science. Prior practice and opinion appear to play a strong part in determining what procedures are used.

Water quality has little correlation to the meter cleaning and overhaul practices, nor is there any correlation between water quality and programs for the replacement of meters.

### Recommendations

Significant economies may be realized in the purchase, testing, and rebuilding of  $\frac{1}{2}$ -in. domestic-service water meters by adopting the following practices where they apply:

1. On meter purchase require compliance with AWWA C705 and C700.

2. Require vendors to supply original or photostatic copies of their test records on meters furnished.

3. Sample-inspect new meters on the basis of a statistically valid acceptance plan.

4. Reduce used-meter cleaning to the simplest practical terms.

5. Require repaired meters to meet the recommended accuracy requirements of AWWA C705.

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## Evaluation of Methods for Coliform Counts in Farm Pond Waters

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*A contribution to the Journal by George W. Malaney, Asst. Prof.; Harry H. Weiser, Prof.; and Robert M. Gerhold and Fred A. Garver, Research Assts.; all of the Dept. of Bacteriology, Ohio State Univ., Columbus, Ohio.*

ONE solution to the current water shortage in some areas seems to lie in the construction of small surface water impoundments. Most mid-western states report the appearance of hundreds of new ponds yearly. In many instances ponds have provided water in sufficient quantity to satisfy increasing demands on the farm, but quantity alone is not the complete answer; quality is equally important. The quality of these pond waters, from the bacteriologic point of view, is virtually unexplored. Many farm homes are utilizing pond waters which have received grossly inadequate treatment or no treatment at all. These ponds are, of course, susceptible to excremental pollution, and the sanitary quality of farm pond waters is, therefore, of public health interest. The study reported below is a direct outgrowth of a sanitary survey of selected representative farm pond waters and treatment facilities on farms in Ohio.

### MF and MPN Results

It was initially decided that evaluation of the sanitary quality of the untreated pond water be based upon coliform density as determined by the

membrane filter technique. The two-step method recommended by *Standard Methods*<sup>1</sup> was followed as closely as possible. Molecular filter membranes\* (47 mm) and M-Endo broth with BGF indicator were employed. Water samples were taken from the deepest part of the pond, one foot below the surface and one foot from the bottom. The size of the sample filtered varied from 1 to 100 ml, but was usually 20 ml.

Estimation of coliform population by the fermentation tube method was run in parallel with the MF method. The MPN was determined according to *Standard Methods* using five tubes of lactose broth per dilution and three dilutions per sample. Positive presumptive tubes were confirmed in brilliant green lactose bile broth (BGB), 2 per cent.

The coliform densities of individual samples of farm pond water are given in Table 1. Ninety-four samples were examined in parallel by the MF and MPN-BGB techniques. Approximately half of the samples were top samples and the remainder bottom samples. In 30 samples the MF and

\* Millipore, HA Type; manufactured by Millipore Filter Corp., Bedford, Mass.

MPN results were in agreement (31.9 per cent). The MF value was considered to be in agreement with the MPN value if the coliform density determined by the MF method fell within the 95 per cent confidence limits of the corresponding MPN value.<sup>2, 3</sup> Using statistical concepts based upon the Poisson distribution, the 95 per cent confidence limits for a 5-tube, 3-dilution test have been defined as 0.3 times the MPN and 2.9 times the MPN. For example, if the experimental data gave an MPN of 100, it

would be right 95 per cent of the time to say that the true coliform population in the sample falls between 30 and 290. If the coliform estimation by the MF method were any density between 30 and 290, inclusive, it would be considered in agreement with the MPN. A basic assumption in this phase of the study was that the MPN-BGB method gave a reliable estimation of the coliform population.

Of the samples in agreement, sixteen were top samples and fourteen were bottom samples, which suggests that

TABLE 1  
*Coliform Density of Farm Pond Water as Determined by MPN and MF Techniques, July-September 1958\**

Top		Bottom		Top		Bottom	
MPN	MF	MPN	MF	MPN	MF	MPN	MF
Count per 100 ml				Count per 100 ml			
>2,400	<10	540	180†	68	30†	230	30
>2,400	<10	>2,400	100	490	60	110	110†
920	350†	1,600	160	170	10	7,900	210
		1,600	<100	220	43	7,900	240
>2,400	<10	>2,400	<10	700	350†	4,900	760
>2,400	<10	>2,400	<10	45	32†	140	13
>2,400	<10	>2,400	<10	110	10	9,200	40
78	<10	490	65	170	20	170	100†
2,400	900†	210	500†	2,800	770	370	980†
1,400	550†	790	470†	170	58†	78	110†
790	380†	170	340†	330	<10	5,400	6,500†
330	20	78	20	40	30†	2,300	550
5,400	680	9,200	970	430	<5	95	10
490	380†	>24,000	710	170	5	220	60
170	<10	3,500	130	20	5	78	15
5	<5†	920	25	70	23†	350	<5
79	10	350	20	170	10	140	<10
220	15	1,400	670†	700	360†	9,200	390
		>24,000	7,200	4,900	3,400†	7,900	2,300
1,700	270			2,200	1,000†	5,400	1,500
2,400	400	460	235†	2,400	1,200†	3,300	600
>24,000	2,700	16,000	1,100	9,200	130		
2,100	170	260	90†	5,400	200	1,700	350
310	75	110	50†	140	8	490	43
700	55	330	160†				

\* Data arranged chronologically.

† MPN and MF in agreement—that is, MF result fell within 95 per cent confidence limits of corresponding MPN.

sample location in depth did not significantly influence agreement. It can be seen from Table 1 that frequently a sample with a high MPN showed a very low coliform count by the MF method.

Agreement between the two methods was not as close as that reported for other types of water. The MPN of individual samples was invariably higher than that of the same water analyzed by the MF technique, a fact previously reported by numerous workers. For example, Thomas and Woodward<sup>4</sup> found the MPN to be larger by a factor of 1.0-1.9 with an average of 1.3. In the present study the mean MPN was greater than 2,700 while the mean MF was less than 460, a ratio of at least 6:1. Indeterminate coliform densities made it impossible to calculate the value of means exactly. By the 95 per cent confidence limits criterion, only 31.9 per cent of the MF values were in agreement with the corresponding MPNs. This would seem to be poor agreement. Of much greater consequence is the fact that in numerous samples the MF technique indicated a very low concentration of coliform organisms, whereas the corresponding MPN value indicated that they were present in considerable numbers.

#### Reliability of MF and MPN Methods

Such divergent results raised a question as to the reliability of the MF technique for the determination of coliform densities in this type of water, as it was assumed that the MPN-BGB method gave a close approximation of its coliform population. Kabler,<sup>5</sup> however, has pointed out that recent work had shown frequent discrepancies between the "confirmed MPN" and the "completed MPN" results for water

from small impoundments. This suggested shortcomings in the MPN-BGB method. For example, Shane<sup>6</sup> reported that 48-hr positive tests in confirmatory BGB seldom give a positive completed test.

The reliability of a positive BGB confirmatory reaction was investigated in three samples from different ponds by running the *Standard Methods*

TABLE 2

*Comparative Coliform Densities of Farm Pond Waters by Four Standard Methods, July-September 1959*

Depth of Sample*	Count per 100-ml Sample			
	MF	MPN-BGB	MPN-BGB-SMC	SMC
B	350	1,100	1,100	11
T	75	490	95	41
T	190	350	280	32
B	25	130	110	21
T	<20	79	17	6.8
B	63	17	17	17
T	50	49	22	17
B	<10	17	4.5	7.8
T	2,500	9,200	280	480
B	12,000	560	370	170
T	25	330	330	330
B	8	80	4	70
T	46	170	70	79
B	38	70	17	22
T	250	1,400	950	390
B	300	440	280	440
T	69	31	23	23
B	62	79	27	49
T	38	220	21	17
B	170	260	21	34
T	23	17	4	11
B	23	170	11	6.1
T	23	33	12	17
B	1,000	430	240	390
T	8	46	6.8	110
B	8	70	21	2
T	69	170	21	27
B	15	260	17	110
T	170	1,700	38	1,100
B	230	1,100	39	40
T	15	490	140	95
B	69	210	33	130
T	100	330	11	14
B	100	49	13	21
T	8	33	6.8	23
B	69	220	21	21
T	380	490	220	140
B	370	110	62	540
T	1,900	9,200	170	240
B	2,400	9,200	540	280
T	120	170	110	26
B	85	330	48	170
T	810	5,400	390	140
B	480	3,500	120	240
T	54	130	130	70
B	92	180	140	26
Mean	540	1,070	144	136

\* T, top; B, bottom.

completed test (SMC) on all BGB tubes showing gas production. Of 31 positive BGB tubes, only 9 were shown by the SMC to contain coliform organisms, indicating a high percentage of false positive tubes.

### Results by Four Procedures

The coliform population of each sample was estimated in parallel by:

1. The MF technique
2. Inoculation into lactose broth with confirmation in BGB (MPN-BGB)
3. Continuation of the MPN-BGB procedure with transfer of all positive BGB tubes to EMB agar, then to lactose broth and agar slant (MPN-BGB-SMC)
4. The *Standard Methods* completed test (SMC)—lactose broth to EMB agar to secondary lactose broth and agar slant.

For each of the three MPN methods the starting point was the same set of inoculated lactose broth tubes. The results are given in Table 2.

In this series it is assumed that method MPN-BGB-SMC gives the closest approximation of the true coliform population, because it makes use of the greatest number of selective and purification steps. Therefore, MPN-BGB-SMC results are used as a standard against which the results obtained with the other methods are compared. The average (arithmetic mean) of coliform densities by each method are shown in Table 2. In terms of these average values the SMC results were very close to MPN-BGB-SMC results. On the other hand, the MF average was roughly four times and the MPN-BGB average approximately nine times that of the MPN-BGB-SMC results, which indicates a sizeable discrepancy.

When, for individual samples, the results of the other three methods are checked for agreement with the 95 per cent confidence range for method MPN-BGB-SMC, it is found that the MF results were in agreement for 23 samples (50 per cent) with two indeterminate values not included, the MPN-BGB results were in agreement for 19 samples (41.4 per cent), and the SMC results were in agreement for 32 samples (69.7 per cent).

TABLE 3  
*Comparison of Results by Four  
Standard Methods*

Results Compared to MPN-BGB-SMC Results	No. of Counts		
	MF Method	MPN-BGB Method	SMC Method
In agreement*			
Higher	15	15	16
Same		4	4
Lower	8		12
Total	23	19	32
Not in agreement			
Higher	18	27	8
Lower	3		6
Total	21	27	14

\* Within 95 per cent confidence limits.

Table 3 was prepared in an attempt to determine whether any method appeared to give high or low results as compared with the MPN-BGB-SMC method. It can be seen that MF results might be higher or lower than the corresponding MPN-BGB-SMC results with a tendency to deviate on the high side. This trend was also evident in the results reported by Adams.<sup>7</sup> The MPN-BGB showed a very strong bias toward higher results than those given by the MPN-BGB-

SMC method. The SMC method gave a fairly uniform distribution of high and low values, which suggests an absence of bias in that method.

### Discussion of Results

It is evident from the experimental data that of the three methods employed the SMC test gave the closest approximation of coliform densities estimated by the MPN-BGB-SMC method, both in terms of average results and for individual samples. Both of these methods are tedious and time-consuming, so a shorter method would be desirable. Unfortunately, both of the simpler methods, the MF and the MPN-BGB, showed considerable deviation from MPN-BGB-SMC results. If the latter method did indeed give the closest approximation of the true coliform population, then the SMC method was most accurate, the MF technique showed sizable discrepancies, and the MPN-BGB method was least accurate.

Several technical difficulties probably contribute to the error in the MF method. One of these is the type of culture medium employed. In the early stages of this investigation, EHC Endo broth and M-Endo broth with BGF indicator were checked for usefulness as differential media. The latter medium, which has been recommended for use with waters containing large numbers of noncoliform bacteria, gave the most satisfactory results and was employed exclusively after Jul. 16, 1958. This medium seemed to inhibit the growth of noncoliform colonies to a greater extent than did the plain Endo medium, although nonsheen-producing bacteria were able to grow in sufficient numbers to cause some crowding of typical coliform colonies on the filters.

Choosing the size of the sample for filtration posed somewhat of a problem. Because highly turbid waters were often encountered it was not always possible to filter a sample large enough to be adequately representative. In many cases, the turbidity caused by algae and suspended material was so great that only 1-2 ml could be passed before the filter clogged. This is undoubtedly a major source of error in the MF method with this type of water.

The method of calculating the coliform density when several membranes are set up on a sample is not given in *Standard Methods*. The authors arbitrarily considered each replicate membrane individually—that is, a coliform density was calculated from the colony count on each membrane, and then the several results were averaged to obtain the density for the sample. The authors are of the opinion that a standard scheme for calculating the density should be specified in *Standard Methods*.

The error in the MPN-BGB method for farm pond waters apparently derives from the presence of bacteria which are capable of growing and fermenting lactose despite the inhibitory compounds in BGB broth. An attempt to isolate the types of organisms causing this interference is currently underway.

### Conclusions

In an effort to determine the most accurate method for estimating the density of coliform organisms in untreated farm pond water, 46 samples were analyzed in parallel by:

1. The membrane filter technique
2. The MPN method with confirmation on BGB broth

3. The MPN-BGB method, followed by the SMC test on all positive BGB tubes

4. The SMC test alone.

If it is assumed that the MPN-BGB-SMC method gave the closest approximation of the true coliform population, then, in terms of both average and individual results, the SMC method was most accurate, MF results tended to be somewhat high, and the MPN-BGB method showed a definite bias toward high values.

The results emphasize the need for exercising care in the choice of method for determining coliform density of moderately polluted water in small impoundments, such as farm ponds. The BGB-confirmed test should not be employed unless it is certain that results from this method are in accord with results from the completed test on a particular water source.

#### Acknowledgments

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Acknowledgment is also made of important technical assistance by Ron Hill, Department of Agricultural Engineering, Ohio State University.

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# Effect of Fish Poisons on Water Supplies

## Part 2. Odor Problems

**Jesse M. Cohen, George A. Rourke, and  
Richard L. Woodward**

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*A contribution to the Journal by Jesse M. Cohen, Chemist; George A. Rourke, Chemist; and Richard L. Woodward, Chief, Eng. Sec., all of Water Supply & Water Pollution Research Branch, Robert A. Taft San. Eng. Center, Cincinnati, Ohio. This is the second of three articles on the effect of fish poisons on water supplies. Part 1, dealing with the removal of toxic materials, was published in the December 1960 Journal. Part 3 will discuss a field study.*

**I**N a previous article<sup>1</sup> the problems of treating water containing a fish poison were discussed, and data were presented on the ability of various water treatment processes to remove the toxic agents deliberately added to a water during fish management operations. This article reports the results of experiments aimed at assessing the odor potential of various fish poison formulations and the ability of water treatment processes to remove these odors.

### Materials

Pure rotenone or toxaphene, currently the principal toxic agents used in fish poisons, are practically never used alone for fish management operations. For ease of handling and to enable effective dispersion, these toxic materials are invariably formulated with other materials that include synergists, solvents, emulsifiers, or clay carriers. Hence, in addition to the materials previously studied, selected solvents were also investigated. Compounds that were studied are listed in Table 1.

### Methods

One of the fish poisons, Formulation D, was studied in detail. In addition to a determination of threshold odor concentration of the material itself, removal of odor from water was attempted by several treatment processes that included activated-carbon adsorption, alum coagulation, and chlorination. In each of these studies, effectiveness of removal was judged by determination of odor reduction. Results from the detailed study of this particular formulation quickly demonstrated that the only effective means for odor removal was treatment with activated carbon. Therefore, only this treatment process was applied to the other formulations and fish poisons. Some of the materials, because of their high threshold odor concentrations, were not studied for odor removal because they would present no odor problems at water plants when used under normal conditions.

### Threshold Odor Concentration

The minimum amount of formulation or component that will produce

a detectable odor was obtained by determining the threshold odor concentration. For purposes of this study, the threshold odor concentration is defined as the smallest amount of material in aqueous solution or emulsion whose odor is detected by 50 per cent of the test panel. The test and computations were made in the following manner:

A stock solution of a known concentration of material was prepared in

TABLE 1

*Fish Poisons and Other Materials Studied*

Name of Material	Constituents of Material
Formulation A	rotenone, rotenoids, toxaphene, solvent, emulsifier, clay
Formulation B	rotenone, rotenoids, solvent, emulsifier
Formulation C	rotenone, rotenoids, synergist, solvent, emulsifier
Formulation D	rotenone, rotenoids, solvent, emulsifier
Rotenone	rotenone
Toxaphene	toxaphene
Sulfoxide	synergist
Aerosol OT	emulsifier
Solvent 1	solvent
Solvent 2	solvent
Solvent 3	solvent
Deodorized kerosene	solvent

odor-free Cincinnati tap water. When solubility was exceeded, a fine emulsion was obtained by the addition of a solution of the material in isopropyl alcohol to the water and emulsification in a blender for 5 min. The addition of small amounts of isopropyl alcohol was shown not to interfere with the determination of threshold odor concentration, and the method invariably produced a sufficiently stable emulsion.

Successive serial dilutions by a factor of two were then made of the stock solution, and 200-ml portions were placed into 500-ml, glass-stoppered, odor-free erlenmeyer flasks. This series of flasks containing decreasing amounts of material, along with blanks that contained only odor-free water, were appraised for the presence or absence of odor by a panel of eight individuals. Computation of the average threshold odor concentration was obtained by a "moving-average" method.<sup>2</sup> This method may be illustrated by the determination of the threshold odor concentration of toxaphene, which is typical of all of the compounds that were tested.

A stock solution of toxaphene in isopropyl alcohol was added to 400 ml of odor-free tap water and emulsified in a blender for 5 min. Successive twofold dilutions were prepared and dispensed into glass-stoppered erlenmeyer flasks and then submitted to a panel of observers. Computation of the threshold odor concentration is shown in the Appendix. Threshold odor concentrations were determined for all of the pure compounds, formulations, and solvents listed in Table 1. The data obtained, along with the computed 95 per cent confidence limits, are shown in Table 2.

Rotenone has a high threshold odor concentration, but toxaphene, with a threshold odor concentration of 0.005 mg/l, would cause an odor problem in water. The very low threshold odor concentration of the commercial fish poison formulations tested, ranging from 0.007 mg/l to 0.023 mg/l, is largely the result of the solvents that constitute as much as 90 per cent of the product.

The varieties of solvents available to commercial formulators are so great

that, for this study, only representative solvents could be investigated. Proper selection of a solvent could yield a fish poison formulation that is practically odorless. It is evident that odor potential has received little or no attention in the selection of solvents currently being used in fish poison formulations.

### Activated-Carbon Treatment

The experimental methods used in studying the removal of contaminants

TABLE 2  
*Threshold Odor Concentrations of  
Fish Poison Formulations and  
Components*

Material	Threshold Odor Con- centration mg/l	95 per cent Con- fidence Limits	
		Upper	Lower
Formulation A	0.020	0.028	0.018
Formulation B	0.023	0.033	0.015
Formulation C	0.007	0.009	0.005
Formulation D	0.018	0.025	0.011
Cube powder	30.6	41.6	24.0
Rotenone	13.8	23.1	9.6
Toxaphene	0.0052	0.010	0.0022
Sulfoxide	0.091	0.17	0.05
Aerosol OT	14.6	23.1	10.3
Solvent 1	0.016	0.021	0.004
Solvent 2	13.9	20.5	8.1
Solvent 3	0.090	0.143	0.057
Deodorized kerosene	0.082	0.106	0.057

by activated carbon have been fully described in a previous article.<sup>1</sup> In brief, a fixed concentration of contaminant was treated with varying amounts of activated carbon. After removal of the carbon by filtration through a sintered glass filter, the residual threshold odor number was determined by a panel of eight observers. From this, the concentration of the contaminant is estimated by the formula:

Concentration of contaminant

$$= \frac{\text{Threshold odor concentration}}{\text{Threshold odor number}}$$

The threshold odor number is expressed as a dilution factor.

For example, toxaphene has a threshold odor concentration of 0.005 mg/l. After treatment of 2.0 mg/l toxaphene with 10 mg/l activated carbon, it was found that the treated water had a threshold odor number of 152. In other words, the sample had to be diluted 1:152 to obtain a non-odorous water. Expressed as a dilution factor, the threshold odor number becomes 0.0066. The concentration of chemical remaining in the water after carbon treatment is then obtained by the foregoing equation, which becomes:

Concentration of toxaphene

$$= \frac{0.005}{0.0066} = 0.76 \text{ mg/l.}$$

Data obtained in this manner were used to construct carbon adsorption isotherms according to Freundlich's equation. Such isotherms were obtained for the pure fish poisons and solvents and for the fish poison formulations. Computations were also made for all the compounds, with the use of the parameters derived graphically from the adsorption isotherms, to determine the amount of carbon required to reduce any concentration of fish poison to a predetermined level. This method of calculation was described in the previous article.<sup>1</sup>

Typical laboratory data for Formulation C are shown in Table 3. As shown in Table 1, Formulation C contains, in addition to rotenone, a synergist and a highly odorous solvent. Also shown in Table 3 are the functions for the construction of an adsorption isotherm. The resulting car-

bon adsorption isotherm for Formulation C is shown in Fig. 1. The considerable scatter of the individual points reflects the lack of precision in odor measurement. Notwithstanding the scatter, a curve may be drawn which correlates adsorptive capacity per unit weight of carbon with concentration of adsorbate remaining in solution at equilibrium.

article.<sup>1</sup> In Fig. 2, two curves are shown which represent the desired residual odor after carbon treatment—the upper curve depicting a residual threshold odor number of 1, which is equivalent to a concentration of 0.0068 mg/l Formulation C; the lower curve representing a residual threshold odor number of 2, or a concentration of 0.0136 mg/l.

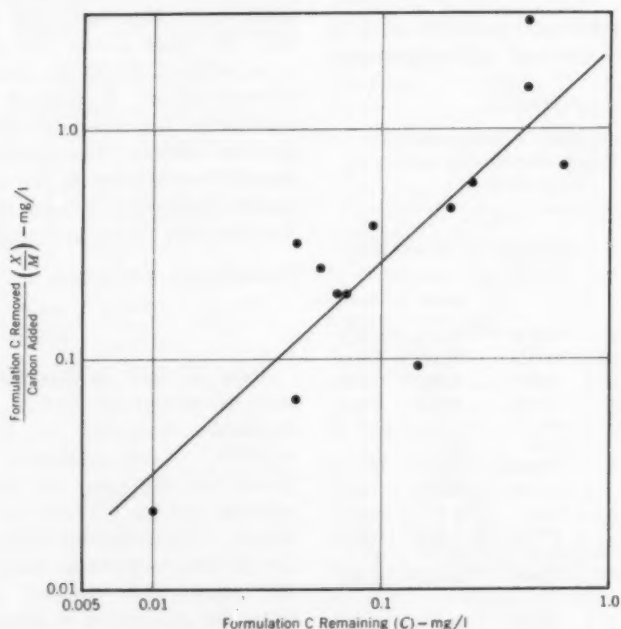


Fig. 1. Carbon Adsorption Isotherm for Formulation C

For the curve, the parameters  $K$  and  $\frac{1}{n}$  in the Freundlich equation were 2.25 and 0.92, respectively.

The parameters  $K$  and  $n$  in the Freundlich equation for the curve in Fig. 1 were obtained graphically and then used to compute the amount of carbon needed to reduce any initial concentration of Formulation C to any desired level. The method of computation was described in the previous

Carbon adsorption isotherms were obtained for all the commercial fish poison formulations, with the use of odor measurement as a quantitative determination of residual chemical. These isotherms (Fig. 3) show, by their position and slope, the intrinsic differences in composition of the for-

mulations. The parameters of the curves are shown in Table 4. It should be pointed out here that an adsorption isotherm for a formulation is a composite of the individual isotherms of the several components. Isotherms for several of these components are shown in Fig. 4. Parameters for these curves are shown in Table 5.

No adsorption data by odor methods were obtained for rotenone, the principal toxic agent in most fish poison formulations. Because the threshold odor concentration of rotenone is so high, 14 mg/l, it would contribute no odor when applied in the normal concentration for field use. The carbon adsorption isotherm of rotenone, as measured by the bioassay method, was, however, shown in the previous article.<sup>1</sup> For the same reason pertaining to rotenone, no adsorption isotherm is shown for sulfoxide. The threshold odor concentration of this material, 0.091 mg/l, is greater than the concentration likely to be present in a water treated with any fish poison formulation. Treatment of a water with 2 mg/l Formulation C would yield a concentration of 0.05 mg/l sulfoxide.

These isotherms provided the data required to plot the curves shown in Fig. 5. It is immediately apparent that a wide range exists between the easily adsorbed and the difficultly adsorbed materials. Formulation A, which contains the smallest amount of odorous hydrocarbon solvent, is most easily removed by carbon, only 36 mg/l being required to reduce the odor of 2.0 mg/l to a residual threshold odor number of 1. On the other hand, Formulation C, which is 90 per cent solvent that has a very low threshold odor concentration, is the most difficult to remove and would require 85 mg/l carbon.

## Chlorination

Other methods of treatment were used in the attempt to remove the odor of Formulation D. Application of chlorine in concentrations as high as 30 mg/l, with a contact time of 3 hr, did not materially reduce the odor, nor was the odor intensified by this application of chlorine. A chlorine

TABLE 3  
*Removal of Odor of Formulation C\*  
by Activated-Carbon Treatment*

Carbon Added (M)† mg/l	Formulation C Remaining (C)† mg/l	Formulation C Removed (X)† mg/l	Formulation C Removed per mg/l Carbon ( $\frac{X}{M}$ )† mg/l
0.5	0.435	1.61	3.23
1.0	0.444	1.60	1.60
2.0	0.615	1.43	0.72
3.0	0.251	1.80	0.60
4.0	0.200	1.85	0.46
5.0	0.093	1.96	0.39
6.0	0.042	2.01	0.33
8.0	0.054	1.99	0.25
10.0	0.068	1.98	0.20
10.0	0.065	1.98	0.20
20.0	0.147	1.898	0.095
30.0	0.043	2.005	0.067
85.0	0.010	2.038	0.024

\* The initial concentration of Formulation C was 2.048 mg/l; the threshold odor concentration, 0.0068 mg/l.

† Freundlich's equation is usually written as:

$$\frac{X}{M} = KC^{\frac{1}{n}}$$

in which  $X$  represents the units of adsorbate held by the carbon;  $M$ , the carbon weight by which adsorption was effected; and  $C$ , the concentration of substance remaining unadsorbed at equilibrium. The two parameters

$K$  and  $\frac{1}{n}$  are particular to the system (see Ref. 1).

demand determination performed on a 2.0 mg/l aqueous emulsion of Formulation D showed no consumption of chlorine and, hence, by itself, Formulation D would not interfere with chlorination at a water plant.

### Persistence of Odor

Because of the difficulty in reproducing field conditions in a laboratory, no attempt was made to determine the persistence of the odor of all the fish poison formulations under all conditions of environment. The persistence of the odor of Formulation D was stud-

periment (Fig. 6) showed that the odor of Formulation D is rapidly dissipated within the first 2 days, with the rate considerably reduced thereafter. After 7 days, 90 per cent of the odor had disappeared from the solution, with a threshold odor number of less than 2 remaining.

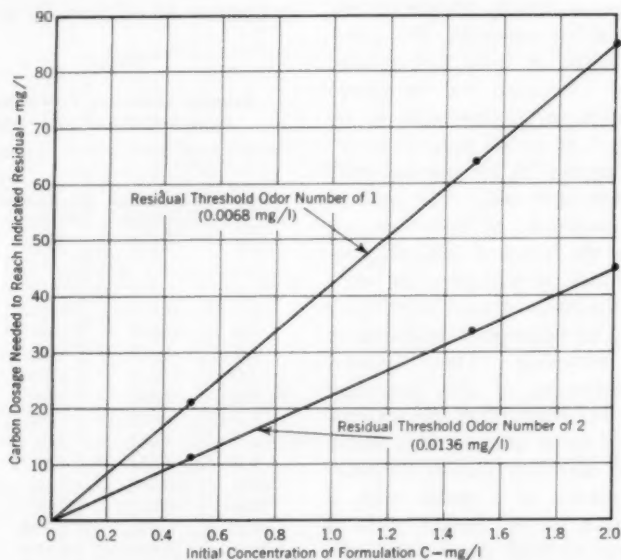


Fig. 2. Carbon Dosages for Removal of Formulation C

The two curves shown represent the desired residual odor after carbon treatment.

ied to provide at least an idea of how long the odor problem would be troublesome where this compound is used.

An emulsion of 2.0 mg/l Formulation D, prepared in odor-free tap water, was put into a wide-mouth gallon jar, covered loosely with a watch glass, and allowed to stand at laboratory room temperature. During the course of the experiment, temperature ranged from 22°C to 25°C. Samples for odor measurement were removed at intervals. The data in this ex-

### Decomposed Fish

Hoffman and Payette,<sup>8</sup> in their report on fish eradication in Hodges Reservoir, San Diego, Calif., show that all fish killed by rotenone do not come immediately to the surface where they may be harvested. As long as 11-13 days after rotenone application, 64.2 tons of partially decomposed fish rose to the lake surface and were recovered. Delayed appearance of dead fish has also been reported in other operations.



Because dead fish would probably remain in the water long enough for decomposition to occur, and because the odor of dead fish is repugnant to consumers, experiments were undertaken to determine the effectiveness of coagulation, carbon treatment, and chlorination in removing the odor.

water was then stored at temperatures of 1–2°C.

A quantitative measurement of the odorous water was obtained by a standard threshold odor determination and by a 30-min chlorine demand determination. The threshold odor number was found to be 2,048 by a panel

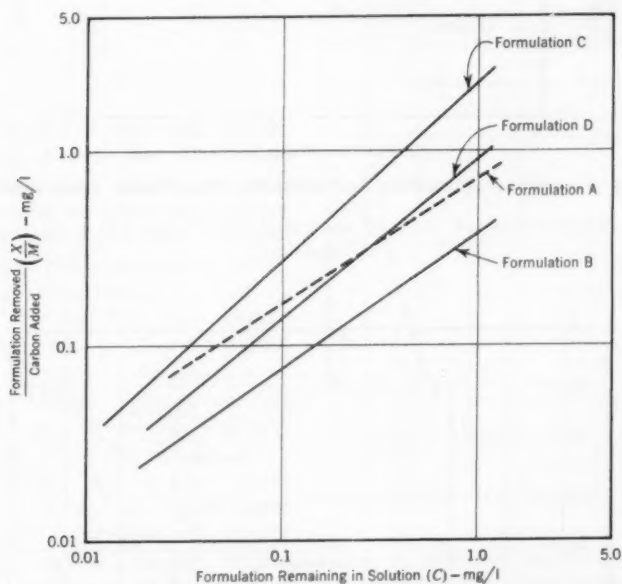


Fig. 3. Carbon Adsorption Isotherms for Commercial Fish Poison Formulations

The initial concentration of each of the formulations was 2.0 mg/l. See Table 4 for parameters.

An approximation of the intensity of odor that might be encountered in practice was computed on the assumption that the worst conditions existed. To produce an odorous water, twenty fish, weighing a total of 24 g, that had been killed by rotenone were put into 20 liters of test water and allowed to stand for 2 days at a room temperature of 21°C. The decomposed fish were removed, and the odorous

water was then stored at temperatures of 1–2°C. Determination of chlorine demand revealed that a classical type of curve is obtained (Fig. 7). The 30-min total chlorine demand was 68 mg/l. The sharp "break" in the curve may be attributed to the presence of ammonia and amines, especially trimethylamine, which are frequently associated with decomposing fish.<sup>4</sup>

*Alum coagulation.* Effectiveness of alum coagulation in removing odor and

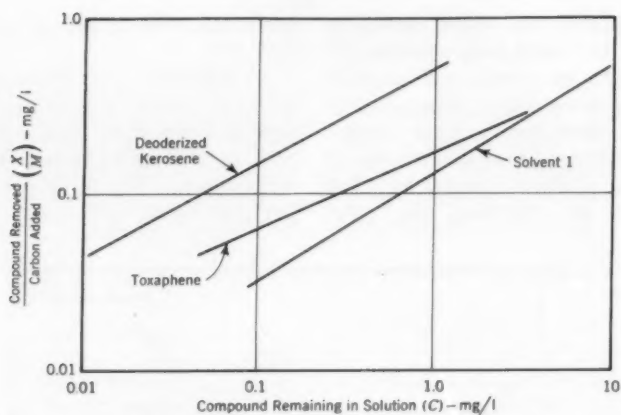


Fig. 4. Carbon Adsorption Isotherms for Fish Poison Components

The initial concentration of each of the components was 2.0 mg/l. See Table 5 for parameters.

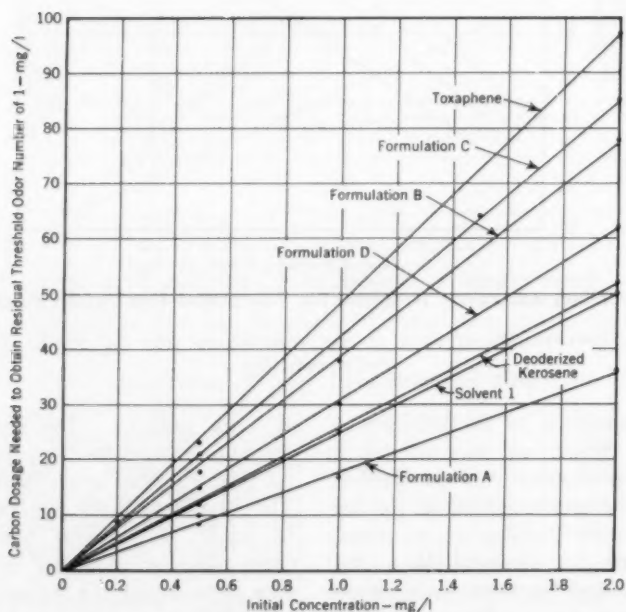


Fig. 5. Carbon Dosages for Removal of Fish Poison Formulations and Components

Formulation A, which contains the smallest amount of odorous hydrocarbon solvent, is most easily removed by carbon.

TABLE 4  
Parameters of Isotherms for  
Formulations in Fig. 3

Formulation	Parameters	
	K	$\frac{1}{N}$
A	0.72	0.65
B	0.37	0.70
C	2.25	0.92
D	0.88	0.82

chlorine demand compounds of decomposed fish in water was determined by coagulating, with varying amounts of alum, a solution containing 10 per cent by volume of odorous water. Both odor and chlorine demand determinations were performed on the effluents. Water that had been treated with 90 mg/l alum produced an effluent with a threshold odor number of 128 and a chlorine demand of 6.5. These values correspond fairly closely to a simple 1:10 dilution of the odorous water, which would give values of 205 and 6.8 for threshold odor number and chlorine demand, respectively. Alum coagulation alone, therefore, has no significant effect on either odor or chlorine demand and will not produce a palatable effluent.

**Carbon treatment.** Odor removal by activated carbon was checked by add-

ing increasing amounts of carbon to a 5 per cent solution by volume of odorous water. As in the previous tests, threshold odor number and chlorine demand determinations were made on the effluents.

Treatment with 40 mg/l carbon completely removed all the odor. A threshold odor number of 2 was obtained with 30 mg/l carbon. Significantly, the chlorine demand of the

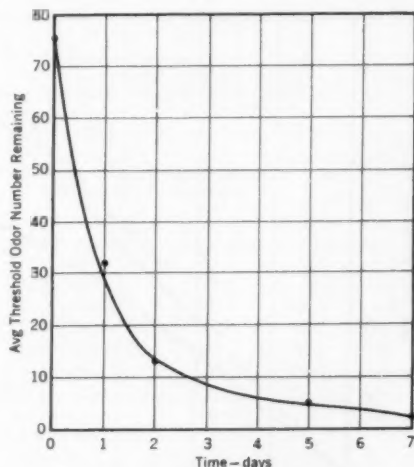


Fig. 6. Reduction of Threshold Odor Number of Formulation D With Time

An emulsion of 2.0 mg/l Formulation D was allowed to stand at room temperatures in the range of 22–25°C.

effluents was not materially reduced. These results indicate that the odor of the decomposed fish was caused by protein decomposition products other than amines and ammonia. The latter compounds apparently resist adsorption by carbon and exert a chlorine demand even after treatment with carbon.

**Chlorine treatment.** A further test was made on the effect of varying

TABLE 5  
Parameters of Isotherms for  
Components in Fig. 4

Component	Parameters	
	K	$\frac{1}{N}$
Toxaphene	0.16	0.43
Solvent 1	0.14	0.53
Deodorized kerosene	0.52	0.62

doses of chlorine in concentrations less than and greater than the chlorine demand value. Concentrations of chlorine in the range of 0.9–4.6 mg/l were added to a 5 per cent solution by volume of odorous water. Dilution of the odorous water to 5 per cent yields a threshold odor number of 10 and a chlorine demand of 3.4 mg/l. The results show that the odor-producing compounds are readily destroyed by

odor produced by decomposing fish can be removed by activated carbon or by free residual chlorination.

### Conclusions

The presence of a fish poison formulation in a water supply poses two basic problems to a water treatment plant: (1) removal of the toxic component and (2) reduction of odor to a level allowing water to remain pota-

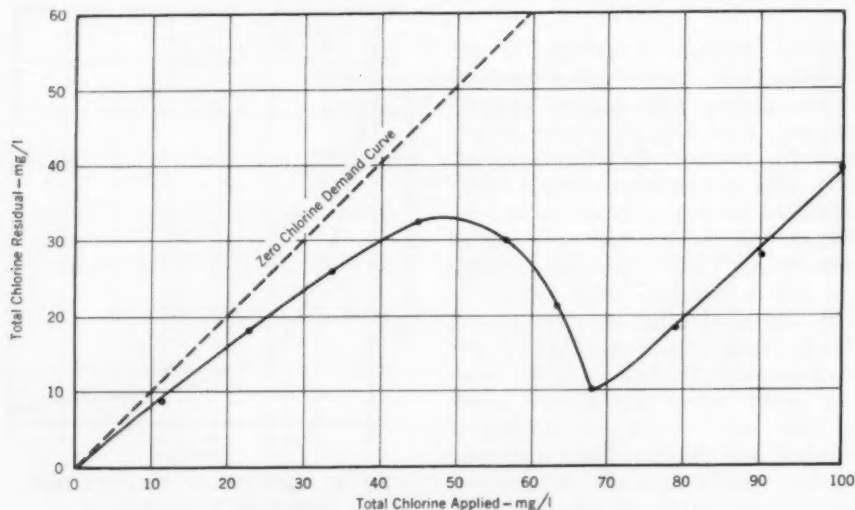


Fig. 7. Chlorine Demand of Odorous Water

*The contact time was 30 min.; temperature, 21°C; and pH, 7.3.*

small concentrations of chlorine; 1.8 mg/l chlorine produced an effluent with a threshold odor number of 1, and 4.6 mg/l chlorine provided an odor-free effluent.

No estimate is available on the intensity of the odor that may appear in a water after fish poison application. Certainly, field conditions will determine the numbers of fish that will evade harvesting. It is clear from the experimental work, however, that

ble. Of the two, the latter problem is the one more likely to prove troublesome to the water plant, because toxicity of fish poisons is removed by much smaller doses of carbon than are required to remove odor.

Data in Tables 2 and 6 reveal the significant fact that almost all the odor in fish poison formulations, with the exception of the formulation containing toxaphene, is caused by the solvent content. Removal of the odor

caused by the solvent also requires the major portion of carbon needed for odor reduction of the formulation. For example, Solvent 1, with a threshold odor concentration of 0.016 mg/l, comprises almost all the odorous material in Formulation D, which has a threshold odor concentration of 0.018 mg/l. To remove this odorous solvent contained in 2.0 mg/l Formulation D requires 62 mg/l carbon; 50 mg/l is required to remove the odor of the solvent when the active materials are not present. The difference in carbon requirement may be ascribed to the presence of emulsifier and rotenoid compounds that could affect the carbon adsorption to this degree.

Although the types of solvents currently used in fish poison formulations have undoubtedly met all of the manufacturer's requirements of low cost, solubility of rotenoids and emulsifiers, ease of application, and successful dispersion, this study has uncovered serious disadvantages in the use of the present formulations in water supply reservoirs. Application of 2.0 mg/l of any of the formulations tested renders a water unpalatable and requires treatment with as much as 85 mg/l activated carbon to produce potable water. Further, although odor may be successfully reduced with activated carbon, no information exists on the removal of unknown, and possibly dangerous, materials from the solvent. These solvents are derived from the distillation of petroleum and coal tar crudes, and their exact composition is not known. Addition of materials of unknown composition to a water supply is not a good practice.

For the above reasons, it would be desirable that a more suitable solvent be developed for use in fish poison formulations intended for application

to water supply reservoirs. In addition to the usual requirements for a solvent demanded by the manufacturer or user, solvents should: (1) have a high threshold odor concentration (the solvent should produce little or no odor when suspended or dissolved in water in a concentration of 2.0 mg/l); (2) be nontoxic to humans and other mammals; (3) be of known composition; and (4) be readily dissipated by

TABLE 6  
*Carbon Requirements for Removal of  
Toxicity and Odor Caused by  
Fish Poisons*

Compound	Initial Concentration mg/l	Carbon Required mg/l	
		Toxicity*	Odor†
Rotenone	0.1	6.6	—§
Toxaphene	0.1	5.0	5.0
Cube powder	2.0	9.8	—§
Formulation A	2.0	8.8	36
Formulation B	2.0	26.4	78
Formulation C	2.0	21.6	85
Formulation D	2.0	16.7	62
Solvent 1	2.0	—‡	50
Deodorized kerosene	2.0	—‡	52

\* Concentration of carbon required to reduce the compound to one-half of 96-hr TL<sub>m</sub> value. These data were taken from the previous article.<sup>1</sup>

† Concentration of carbon required to reduce the odor of the compound to a threshold odor number of 1.

‡ Material is nontoxic to fish in the concentrations normally used.

§ Material is nonodorous in the concentrations normally used.

natural and biologic agencies after dispersion in a water. These characteristics are met by such solvents as acetone or isopropyl alcohol. Certainly, other such solvents are available.

### Summary

Odor in a raw-water supply occurring after contamination with the fish poisons tested may be removed effectively by activated carbon. No other

common water treatment process will successfully reduce the odor of 2.0 mg/l of fish poison formulation to acceptable levels. The doses of carbon required for the formulations tested in this study were 36–85 mg/l. Such carbon doses are unusually large and would be a serious economic burden in the routine treatment of water. But because fish poison formulations would be applied infrequently and because the odor of most of the formulations persists for only a short time, during which interval decreasing dosages of carbon are required, the increased cost of water treatment may not be very large. Use of formulations containing toxaphene would require sustained treatment with carbon because of the high stability of toxaphene.

Because of the unusual odor problem and unknown composition of the

solvents presently used in fish poison formulations, it is recommended that a more suitable solvent be developed for use in formulations intended for water supply application. It must be emphasized that, because fish poison formulations are subject to changes at the discretion of the manufacturer, the data reported in this paper are valid only for the samples tested.

### Acknowledgment

The authors wish to thank these workers from the Taft Center: L. J. Kamphake, chemist, Water Supply & Water Pollution Research Branch, and H. D. Shearer, senior assistant sanitary engineer, Radiological Pollution Activities, for their help in the laboratory; and K. A. Busch, analytical statistician, Statistics Section, for assistance with the statistical analyses.

## APPENDIX

### Computation of Threshold Odor Concentration of Toxaphene

Results of the panel observations for the various concentrations of toxaphene are shown in Table A1. Computations of the threshold odor concentration are then made by tabulating the data, as shown in Table A2.

In Column 1 of Table A2, the concentrations tested by the panel are listed in decreasing order. The logarithm of these concentrations is tabulated in Column 2. In Column 3, the percentage of positive results obtained by the panel members for each concentration tested is listed in decimal form. Column 4 shows the angles corresponding to the percentage of positive results obtained for any given concentration. Percentages may be con-

verted to degrees with the use of Table XII of Fisher and Yates.<sup>5</sup> In Column 5, the moving averages of the angles listed are taken over a span of three angles.

The value of the threshold odor (TO) concentration is then given by the equation:

Log TO concentration

$$= X_i + (X_{i+1} - X_i) \left( \frac{45 - Y_i}{Y_{i+1} - Y_i} \right) \quad (1)$$

in which  $Y_i$  is the moving average equal to or just less than 45 deg. The log concentration corresponding to this moving average is termed  $X_i$ . The moving average, in degrees, just greater than 45 deg is denoted by  $Y_{i+1}$ . The corre-



sponding log concentration is called  $X_{i+1}$ . Thus, in the above example:

$$Y_i = 40 \text{ deg}, \quad Y_{i+1} = 53 \text{ deg}$$

$$X_i = 0.6021, \quad X_{i+1} = 0.9031.$$

The log of the threshold odor concentration is then given by:

Log TO concentration

$$= 0.6021 + (0.9031 - 0.6021) \left( \frac{45 - 40}{53 - 40} \right)$$

$$\text{Log TO concentration} = 0.7178.$$

The antilog of the threshold odor concentration is then equal to the threshold

TABLE A1

*Determination of Threshold Odor Concentration of Toxaphene*

Toxaphene Concentration $\mu\text{g./l.}$	Panel Observations							
	1	2	3	4	5	6	7	8
128	+	+	+	+	+	+	+	+
64	+	+	+	+	+	+	+	+
Blank	-	-	-	-	-	-	-	-
32	+	+	+	+	+	+	+	+
16	-	+	+	+	+	+	+	+
8	-	+	+	+	+	+	+	+
Blank	-	-	-	-	-	-	-	-
4	-	+	+	+	-	+	-	-
2	-	+	+	-	-	+	-	-
1	-	+	-	-	-	+	-	-
0.5	-	-	-	-	-	-	-	-
0.25	-	-	-	-	-	-	-	-

odor concentration. For toxaphene, this value is 0.0052 mg/l.

An extension of this method of calculating the average threshold odor concentration may be used to compute 95 per cent confidence limits for the true threshold odor—that is, limits which will, with a probability of 0.95, include the true threshold odor value.

The following equations represent an extension of results obtained by Bennett<sup>2</sup> and have been published in more general form by Harris<sup>6</sup>:

$$A = \frac{45 - Y_i}{Y_{i+1} - Y_i} = \frac{X}{Y} \dots \dots (2)$$

$$\text{Variance of } Y = \frac{2 \times 820.7}{9 \times n} \dots \dots (3)$$

in which  $n$  represents the size of the panel.

$$g = \frac{(1.96)^2 \times \text{variance } Y}{Y^2} \dots \dots (4)$$

$g$  must lie between 0 and 1. Compute the values  $A_1$  and  $A_2$  with this expression:

$$\frac{A - \frac{g}{2}}{1 - g} \pm \frac{\sqrt{g}}{1 - g} \sqrt{\left(A - \frac{1}{2}\right)^2 + (1 - g) \cdot \frac{5}{4}}$$

TABLE A2

*Computations of the Threshold Odor Concentration of Toxaphene*

1	2	3	4	5
Concentration Tested $\mu\text{g./l.}$	Log of Concentration	Percentage Positive	Angle deg	Moving Average deg
128	2.1072	1.000	80*	
64	1.8062	0.875	70	76.7
32	1.5052	1.000	80*	73.3
16	1.2041	0.875	70	67.3
8	0.9031	0.625	52	53.3
4	0.6021	0.375	38	40.0
2	0.3010	0.250	30	32.7
1	0	0.250	30	23.3
0.5	-0.3010	0	10*	16.7
0.25	-0.6021	0	10*	

\* For 100 per cent response, the proper angle is  $90 - \arcsin \sqrt{\frac{1}{4n}}$ ; for 0 per cent response, the proper angle is  $\arcsin \sqrt{\frac{1}{4n}}$ .

If the smaller number in the above expression is denoted by  $A_1$  and the larger number by  $A_2$ , the 95 per cent confidence limits for the log of the threshold odor concentration are given by:

Lower confidence limit

$$= L_1 = X_i + (X_{i+1} - X_i)A_1 \dots (5)$$

Upper confidence limit

$$= L_2 = X_i + (X_{i+1} - X_i)A_2 \dots (6)$$

The 95 per cent confidence limits for the true threshold odor concentration are obtained with the antilogs of  $L_1$  and  $L_2$ . In the example shown for toxaphene, these computations result in 0.0022 mg/l and 0.0104 mg/l.

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### Correction

The AWWA Standard for Mill-Type Steel Water Pipe (AWWA C202-60T), which was published in the November 1960 JOURNAL, Vol. 52, pp. 1465-1486, contained an error. Under Sec. 8.3 (Bell-and-Spigot Ends With Rubber Gasket), the final line reading "0.250 in." should be amended to read "0.200 in." The error will be corrected in all reprints of the standard.

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## Methods for Determining Radon-222 and Radium-226

**Frederick B. Higgins Jr., Werner N. Grune, Benjamin  
M. Smith, and James G. Terrill Jr.**

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*A contribution to the Journal by Frederick B. Higgins Jr., Graduate Research Asst.; Werner N. Grune, Prof. of Civ. Eng.; and Benjamin M. Smith, Graduate Research Asst., all of San. Eng. Research Laboratories, Georgia Institute of Technology, Atlanta, Ga., and James G. Terrill Jr., Asst. Chief, Div. of Radiological Health, USPHS, Washington, D.C. The article is based on a thesis by the senior author approved in partial fulfillment of the requirements for the degree of Master of Science in Sanitary Engineering in the School of Civil Engineering, Georgia Institute of Technology, May 13, 1960.*

THE evaluation of human exposure to naturally occurring radioactivity has only become of public health importance in the last few years, although the existence of natural activity has been known for more than 50 years. With the increased concern over the problems of radioactive fallout and the monitoring of areas in the vicinity of nuclear reactors, extensive radiologic surveys have become necessary to determine the existing types and quantities of artificial and natural radioactivities.<sup>1</sup> In some instances, the levels of natural activities discovered have been sufficiently high to cause concern. Because of the recent attention to the problem, few methods of analysis are available which are suitable to the large-scale requirements of an extensive field sampling program.

### **Analytic Methods**

With the discovery of high concentrations of radioactivity in well waters in several areas of Maine and New Hampshire, an excellent opportunity presented itself to aid in the develop-

ment of more specific and efficient methods for the analysis of natural radioactivity. A study to investigate the nature, extent, and effect on consumers of natural radioactivity in ground water supplies in these states was requested of USPHS, which, in turn, requested that Sanitary Engineering Laboratories at the Georgia Institute of Technology in Atlanta perform the field studies necessary for the determination of human exposure. The evaluation of the natural activity to be encountered immediately resolved itself into two distinct phases. The first of these, the development of analytic methods, is discussed herein. The second phase, the analysis of the results of the field program to delineate the occurrence and extent of natural activity, has been studied by Smith and others<sup>2</sup> and is published in this issue of the JOURNAL.

A search of the literature revealed a number of existing methods for the analysis of both radon and radium. It was found, almost without exception, that these methods were designed

for the determination of low concentrations of activity on the order of  $0.1 \mu\mu\text{C/l.}^*$  As a result, the equipment and techniques were generally too complicated and time consuming for practical use with many samples.

a purification train for the removal of carbon dioxide and water vapor from the de-emanating gas; and a pulse or vibrating-reed ionization chamber. Hursh<sup>3</sup> employed nitrogen gas and a purification train consisting of an

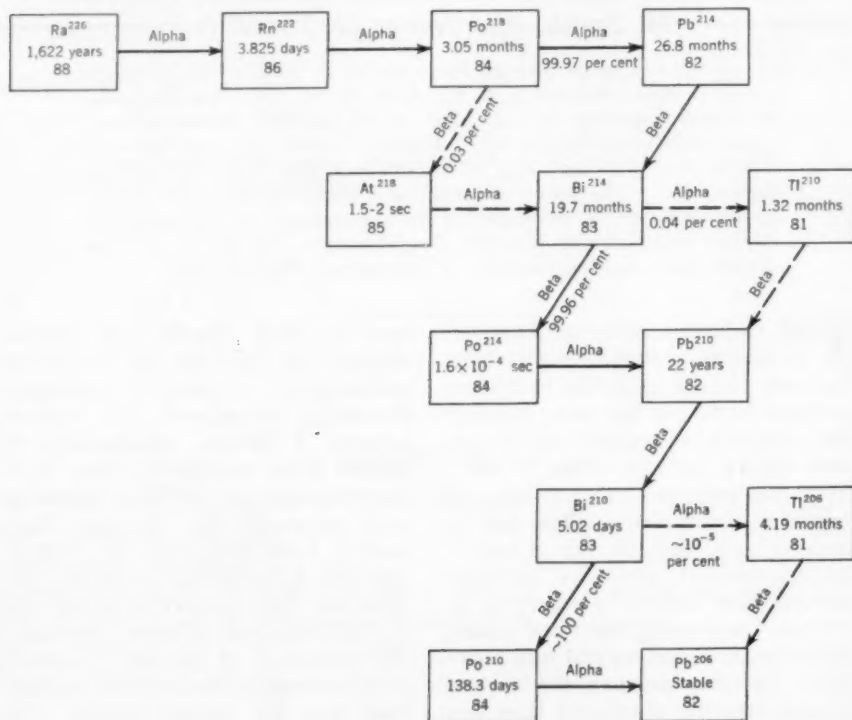


Fig. 1. Decay Scheme of Ra<sup>226</sup>

Beneath the symbol of an element is its half-life and atomic number. The major decay scheme is shown with solid arrows. The type and percentage of radiation is shown on some of the arrows where branching decay occurs (values from Ref. 8).

The typical equipment used consists of an airtight sample container provided with apparatus for bubbling nitrogen or argon through the sample;

acetone-dry-ice water trap and a liquid nitrogen radon trap. The radon was flushed from the liquid nitrogen during heating and was collected in a sample bulb. The radon was transferred from the sample bulb by water displacement into an alpha ionization chamber for counting.

\* A value of  $1 \mu\mu\text{C}$  is the rate of decay of  $10^{-12}$  g of Ra<sup>226</sup>, or 2.22 disintegrations per minute.

Rieck and Perkins<sup>4</sup> described a method of de-emanation with argon while the sample is boiled. They also described a purification train consisting of a reflux condenser, asbestos coated with sodium hydroxide\* for the removal of carbon dioxide, and magnesium perchlorate for removing water vapor. Hudgens and others<sup>5</sup> described a similar procedure, employing nitrogen, with the addition of a column of copper turnings maintained at 500°C and the inversion of the order of the coated asbestos and magnesium perchlorate.

A method employing the de-emanation of radon from a radium solution contained in a special glass bubbler has been reported by Holaday and others<sup>6</sup> for the standardization of air-sampling equipment. D. E. Rushing, in a private communication to one of the authors, proposed that the equipment could be adapted to the analysis of water samples. The investigation of this method was begun in May 1959. Because the field program began during the second half of July 1959, and special equipment had to be constructed, the evaluation of the analytic method was completed in the field. The availability of a large number of naturally radioactive well waters and the comprehensive study program provided an unusual opportunity for a thorough evaluation of the performance and limitations of the method considered.

### Decay and Growth Data

The method and equipment developed for the analysis of radon and radium in water are based on the fact that radon is an inert gas. Therefore,

\* Ascarite, a product of Arthur H. Thomas Co., Philadelphia, Pa.

water containing radon tends to lose radon rapidly to the air with which it comes in contact. The radon is removed by the passing of air through the water; and both radon and air are collected in a flask for alpha scintillation counting.<sup>6</sup>

The portion of the uranium decay scheme of interest in this analysis—that from Ra<sup>226</sup> through Pb<sup>206</sup>—is shown in Fig. 1. When radon is first removed from the water sample, it is free of all daughter products. The radioactive growth equations<sup>7</sup> may then be used to predict the total alpha activity of radon and its daughter products at any subsequent time.

In order to facilitate the use of the growth equations, two simplifying assumptions may be made. The first is that Pb<sup>210</sup> and its daughter products will not build up to significant concentrations during the interval between radon separation and alpha counting. Pb<sup>210</sup> is initially absent and builds up on the basis of a 22-year half-life. A second simplifying assumption is the inclusion of only the major path of branching decay. The most significant branch neglected is the alpha decay of Bi<sup>214</sup> to Tl<sup>210</sup>, which includes only 0.04 per cent of the total bismuth decay.

At any time after radon isolation, the radioactive growth equations may be used, on the basis of the foregoing assumptions, to predict the ratio of the combined Rn<sup>222</sup>, Po<sup>218</sup>, and Po<sup>214</sup> alpha activity to the initial radon activity only:

$$\frac{A_t}{A_0} = 3.009 e^{-0.0001258t} - 1.024 e^{-0.2273t} - 4.280 e^{-0.02586t} + 3.295 e^{-0.83519t}$$

in which  $A_t$  is the activity of Rn<sup>222</sup> plus Po<sup>218</sup> plus Po<sup>214</sup> at any time  $t$ ;  $A_0$ , the initial activity of Rn<sup>222</sup>; and  $e$ , the base of natural logarithms.

A plot of the theoretic growth equation above is shown in Fig. 2. Pertinent theoretic values are shown in Table 1. The curve represents the rising alpha activity from radon. Superimposed on this curve are experimental points tracing the growth of alpha activity from both a standard solution of  $Ra^{226}$  and from water obtained at a residence in Raymond, Me. These points were determined by

study at the Sanitary Engineering Laboratory of the Georgia Institute of Technology.

As a result of preliminary studies, a special type of glass bubbler was developed for the purpose of separating radon from water (Fig. 3). A number of requirements had to be satisfied by this bubbler: (1) the volume had to be large enough to hold a sample containing sufficient radon for analysis,

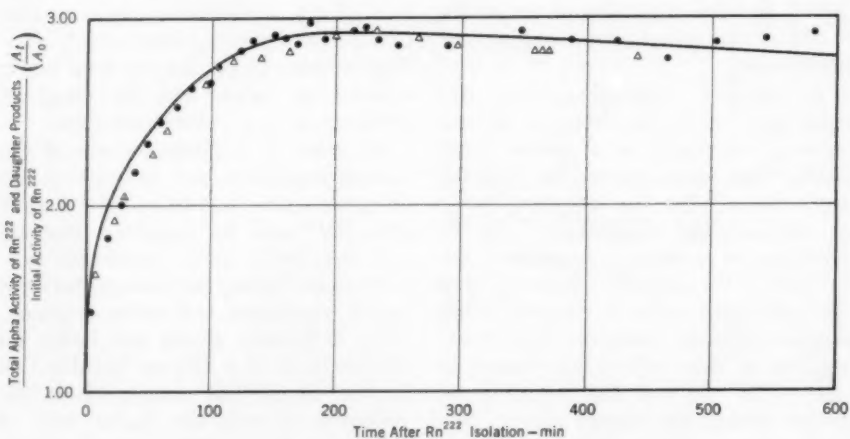


Fig. 2. Growth of  $Rn^{222}$  Alpha Activity After Isolation

Solid circles trace the growth of radon alpha activity from a water sample obtained at Raymond, Me.; triangles, from a standard solution of  $Ra^{226}$ . These are superimposed on a theoretic growth curve. See Table 1 for theoretic values of  $\frac{A_t}{A_0}$ .

means of repeated alpha analyses made over a period of time after radon separation.

#### Equipment and Instrumentation

The equipment required for the analytic procedure under consideration was not available commercially. It included glass sampling devices or bubblers, scintillation flasks, and the scintillation detection unit. Each of these was designed and developed for this

(2) a favorable depth-to-diameter ratio was necessary to insure maximum time of contact between air and water, (3) an air space above the sample was required to allow expansion of the water during bubbling, and (4) a porous plate was required below the sample to disperse the air into uniform bubbles. Consideration of these requirements led to a choice of approximately 40 ml as the bubbler volume; 25 ml of this volume was pro-



vided for the liquid sample and the remainder as a space for expansion of the liquid upon aeration. To provide the necessary agitation and an adequate air-water interface for the de-emanation of radon, fritted-glass filters of medium porosity (Fig. 3) were employed as diffuser plates. A tapered glass stopper was provided for the admission of reagents and the water sample.

The size of the scintillation flask was determined by the diameter of a 3-in. photomultiplier tube and the volume required to insure complete and efficient radon removal from the bubbler. A 125-ml erlenmeyer flask was selected to produce a ratio greater than 1:5 between volume of liquid and volume of de-emanation gas. Holaday and others<sup>6</sup> found that a ratio of 1:4 was needed to produce efficient radon removal from water.

For the detection of alpha particles from the radon activity in the water samples, silver-activated zinc sulfide phosphor was used as a scintillation screen. The screen was inside the flask, because alpha particles have an extremely short range in glass. For the development of the scintillation screen, the inside of the flask was coated with a layer of zinc sulfide crystals<sup>\*</sup> as outlined by Harris, LeVine, and Watnick<sup>9</sup> in a similar procedure.

A special field scintillation detection unit, not commercially available, was designed and assembled at the Georgia Institute of Technology (Fig. 4). The detection unit consisted of four principal parts: (1) a ten-stage, 3-in. photomultiplier tube,<sup>†</sup> (2) a pre-

amplifier, (3) a pulse amplitude discriminator, and (4) a low-voltage power supply. The high voltage necessary for operation of the photomultiplier tube was supplied by a scaler unit.<sup>‡</sup>

### Procedure for Radon Analysis

The sampling and analytic procedures have evolved, after a summer in the field, into a system emphasizing speed and preserving accuracy. The

TABLE 1  
*Theoretic Values of  $\frac{A_t}{A_0}$*

Time min	$\frac{A_t}{A_0}$
0	1.0000
5	1.6783
10	1.9095
20	2.0661
30	2.1704
40	2.2770
50	2.3810
60	2.4766
120	2.8203
180	2.9071
240	2.9120
300	2.8964
360	2.8756
420	2.8543
480	2.8330
540	2.8116
600	2.7905

<sup>\*</sup> Taken, in part, from Ref. 6.

analysis involved the collection of a water sample with minimum aeration, removal and collection of the radon from the water, and analysis by scintillation counting.

*Preparation of bubbler and scintillation flask.* Bubbblers were prepared for use by thorough rinsing with distilled water to remove soluble impurities. After it was cleaned, the bubbler was prepared for sampling by the addi-

<sup>\*</sup> The thickness of the zinc sulfide layer was found, by weighing nineteen samples, to be 5.71 mg/sq cm and to have a 95 per cent confidence interval of  $\pm 0.85$  mg/sq cm.

<sup>†</sup> Model 6363, made by Du Mont Laboratories, Clifton, N.J.

<sup>‡</sup> Model 186, made by Nuclear-Chicago Corp., Chicago, Ill.

tion of 1 ml of concentrated nitric acid through the tapered joint to produce an acid concentration of approximately 0.5N in the sample. The low pH of the resulting solution tended to keep dissolved materials in solution and reduced the contamination of the bubbler. The final preparatory step before sample collection was to weigh the bubbler for subsequent determination of sample volume.

The first step in the preparation of a scintillation flask was to swab the sides of the flask with a solution of

Care was taken to prevent contact of the zinc sulfide powder with the bottom of the flask, as a small amount would cling to the glass, modifying the geometry and interfering with the passage of light. For the application of the coating, the flask was tilted and zinc sulfide poured from a test tube down the wall. By careful tilting and rotation of the flask, a uniform coating was obtained. In order to obtain a slight increase in counting efficiency, the bottom faces of the rubber stoppers were also coated.

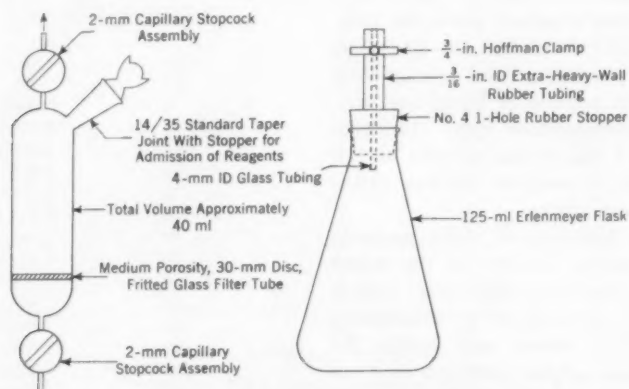


Fig. 3. Bubbler and Scintillation Flask

*The bubbler is shown on the left; the scintillation flask on the right. The equipment,\* not available commercially, was designed at Georgia Institute of Technology.*

approximately one part silicone grease to ten parts chloroform by volume. The chloroform evaporated rapidly and left a layer of grease to hold a uniform coating of zinc sulfide powder. The walls of the flask were coated from the base of the neck to the edge of the flat bottom.

\* Materials for the bubbler are standard items manufactured by Corning Glass Works, Corning, N.Y.: stopcock assemblies, Stock No. 7300; standard taper joint, Stock No. 6580; and filter tube, Stock No. 39570.

The scintillation flasks were found to become contaminated by daughter products of radon after use of each sample with a concentration greater than 500  $\mu\mu\text{C/l}$  radon. Therefore, the flasks had to be washed and recoated. To conserve flasks and to maintain fresh zinc sulfide coatings, each flask was first used for a background count, then for a sample, and finally recoated. The silicone grease layer prevented contamination of most of the surface

of the flask, and no permanent increase in flask activity was noted. The best procedure for washing the flasks was scrubbing with a mixture of chloroform and detergent, then washing with the detergent alone, and finally rinsing with distilled water.

**Sample collection.** Samples were collected directly from faucets so that the true radon concentration exposure of the consumer could be measured as accurately as possible. Before a sample was collected, the faucet was turned on for at least 1 min to insure that the sample came from the pressure tank or the well. As radon tends to escape quite readily, any turbulence in the flow from the faucet would result in a partial loss of radon. To minimize this error, aerators and spray nozzles were removed, and a uniform and smooth flow of water was obtained from the faucet. The bubbler was filled directly under the stream, quickly removed, and stoppered. The maximum time for the entire operation was not allowed to exceed 3-4 sec.

**Radon de-emanation.** Radon was removed from the bubbler and collected in the scintillation flask. The upper capillary tube of the bubbler was connected to the scintillation flask. The rubber tube clamp and one stopcock of the bubbler were opened, and the second stopcock was used to regulate the vacuum-produced flow of air. The air flowing through the bubbler was dispersed by the porous glass plate into small bubbles that scrubbed the radon from the sample. Bubbling was performed as rapidly as possible within a limit imposed by the space provided in the bubbler for sample expansion.

After bubbling had ceased during separation, a partial vacuum remained in the scintillation flask because of head loss in the flow of air through

the bubbler. This loss is proportional to the porosity of the fritted-glass plate and to the depth of the water sample in the bubbler. As the range of alpha particles in air is a function of the air density, the proportion of alpha particles reaching the zinc sulfide in the scintillation flask varies with the partial vacuum. To maintain a more constant counting efficiency, the pressure in the flask was equalized to atmospheric pressure.

Special measures were necessary to allow for the radon concentration of the air in the flask. The problem was overcome by taking an air sample at each radon sampling point with the

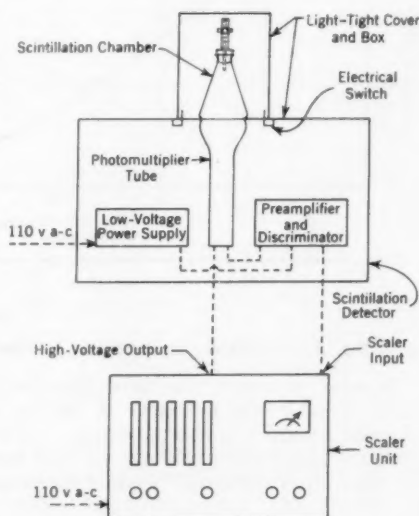


Fig. 4. Scintillation Detector and Scaler

The scintillation detector consists of four principal parts: (1) a photomultiplier tube, (2) a preamplifier, (3) a pulse amplitude discriminator, and (4) a low-voltage power supply. The electrical switches automatically turn off the high voltage when the cover is removed, to protect the photomultiplier tube from damage.

use of only a scintillation flask. The air-sample was counted in the laboratory and used in the same manner as a background count for calculations.

The analyses of the counting efficiency determinations were performed by de-emanating the radon, from a radium standard contained in a bubbler, into a scintillation flask and counting. A comparison of the theoretic activity with the observed ac-

on the efficiency was made over a period of time employing the same standard solutions.

As efficiency varied with time, a plot of efficiency against time was employed in calculations (Fig. 5). The variation in efficiency may be explained in part by the different zinc sulfide phosphors used and by the decay in sensitivity of the photomultiplier tube.

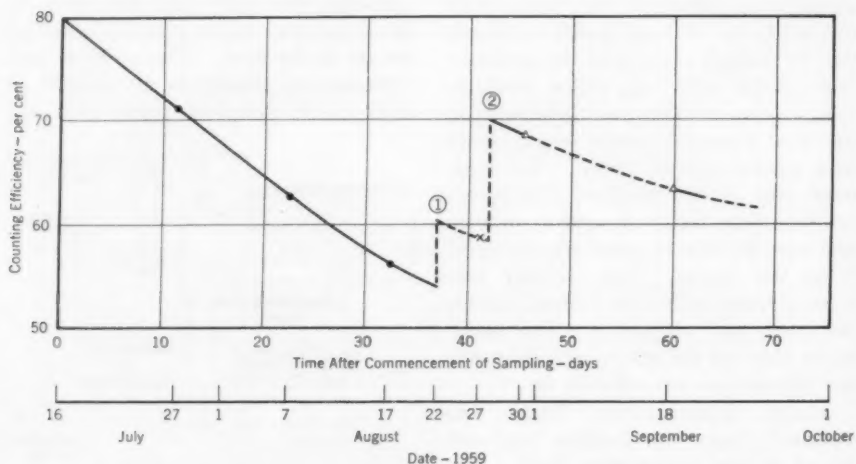


Fig. 5. Variation in Counting Efficiency of Scintillation Detector With Time

The solid portions of the curve represent periods during which the equipment was in use. Solid circles represent an average of four determinations; the cross mark, a recount of two previous standards; and triangles, an average of five determinations. Point 1 shows when the detector was moved to New Hampshire and the sensitivity of the scaler readjusted. Point 2 shows when the new zinc sulfide phosphor was used.

tivity yielded the overall efficiency of the analysis. This method of calibration had the advantage that the bubblers containing the standard solutions could be used again as often as desired. After the remaining radon from the sample was purged, the bubbler could be stored for radon buildup until the next analysis. Thus, a series of checks

#### Procedure for Radium Analysis

The method of analysis described for radon was adapted to radium by a few simple changes in procedure. But, because of the low concentrations of radium found in the natural waters and the small sample capacity of the described bubblers, the accuracy of the determination was not adequate unless

relatively high radium concentrations were encountered.

The procedure for radium analysis involved the storing of a sample of water for a known length of time to allow the buildup of radon from radium, after which a determination of the radon content was made. The sample volume was determined by weighing the bubbler before and after filling. The same sample and bubbler used in the radon analysis were used for the determination of radium.

### Interferences

Radon is the only gaseous product in the natural uranium decay series. As the de-emanation method involves only the removal of gases, there is no possibility of interference from other radioactive materials from this series. Radon present in the atmosphere is a serious interference in the analysis for radium, but is adequately accounted for in radon analysis if an air sample is used in background determination. The radium count rates observed were very low; therefore, the addition of atmospheric radon during bubbling caused background count rates to be several times higher than net sample count rates. The typical background count rate was approximately 5 cpm, although 100 cpm was exceeded in several instances. The alpha activity of air was found to average 9.2  $\mu\text{Ci/l}$ .

A second possible source of interference is the alpha emissions from thoron (Rn<sup>220</sup>) or actinon (Rn<sup>219</sup>) gas in the water sample, if thorium or actinium are present. Thoron has a half-life of 54.5 sec; actinon has a half-life of 3.92 sec. Because of their extremely short half-lives, neither substance is likely to persist in measurable quantities long enough to interfere.

### Reproducibility of Method

The reproducibility of the method was determined from the statistical analyses of three different groups of data. The first group of data was composed of the counting efficiencies from several analyses of each of five standard solutions. The second group consisted of nine triplicates of samples from two sampling points. The third group showed the results from eleven different samples of water from one well in Raymond, Me., collected over a period of about 3 weeks. The latter

TABLE 2  
*Results of Statistical Analyses*

Solutions Tested	Groups of Data		
	$\sigma$ * A.D.	$\sigma$ %	95% Con- fidence In- terval %
All standards	1.33	5.2	10.2
High-activity standards†	1.25	4.5	8.9
Low-activity standards‡	1.48	5.1	10.0
Triplicate samples	1.26	4.7	9.2
Repeated samples	1.22	8.5	16.7

\* The standard deviation divided by the average deviation is 1.25 for normally distributed data.

† 40,000  $\mu\text{Ci/l}$ .

‡ 400  $\mu\text{Ci/l}$ .

group of samples indicates the effect on the confidence limits of well activity variation with time. The results of these analyses are shown in Table 2.

The statistical analyses of reproducibility show that the standard deviations are fairly consistent both between standard solutions of high and low activities and between standards and triplicate samples. The reproducibility is sharply reduced, however, when the time between the collection

of samples becomes significant (as between the standards and triplicate samples as opposed to repeated samples).

The eleven samples taken from one well at Raymond were analyzed as a measure of the variation in well activity with time. The greater value of a standard deviation (Table 2) as compared to that for the standard solutions and replicate samples may be used to measure the variance of the major uncontrollable factor in the analysis, which is the variation of radon activity in the well water with time. The variance of samples from the Raymond well is 72.76, while that of the triplicate samples is only 22.00. The difference may be considered to be the approximate variance of the activity of this one well at Raymond. This value is 50.76, which produces a standard deviation of 7.12 per cent and a range of  $\pm 14.0$  per cent at 95 per cent confidence. Thus, the confidence interval of the variation in activity with time exceeds that of the reproducibility of the method by a factor of 150 per cent. Smith<sup>2</sup> found the activity of a well in South Paris, Me., to vary with time during continuous pumping, reaching a maximum about 15 min after the start of pumping and declining slowly thereafter.

### Conclusions

As a result of the studies of suitable methods for the determination of  $\text{Rn}^{222}$  in water, these conclusions were reached:

1. Verification of  $\text{Rn}^{222}$  as the radioisotope responsible for activity in the well water tested was obtained by the repeated counting of four samples from two wells. The experimentally determined half-life of 3.80 days compares

favorably with the accepted value of 3.825 days.

2. The alpha-counting efficiency of the scintillation detector varied with time because of the decay of the photomultiplier tube. This necessitated frequent measurements and the use of corrections obtained from a graph of counting efficiency plotted against time.

3. The de-emanation method of radon analysis was reproducible on samples to  $\pm 9.19$  per cent, at the 95 per cent confidence level, when the time interval between sampling was short.

4. The radon content of a well was found to vary with time within a 95 per cent confidence interval of  $\pm 14.0$  per cent; thus, the reproducibility of the method, as determined by successive samples from a single source, was reduced.

5. The use of air as a de-emanating gas required the use of airborne radon as the background correction factor in the counting rate of the scintillation detector. This elevated the background level to the point that radium analyses were inconclusive.

### Recommendations

As a result of these studies, the de-emanation method for the analysis of  $\text{Rn}^{222}$  and  $\text{Ra}^{226}$  can be further improved through a number of modifications.

The sensitivity of a photomultiplier tube decays exponentially to a slowly decreasing rate after a period of 1-2 months. Therefore, aging of the tube under full operating voltage prior to use in scintillation detection will eliminate the rapid initial decrease in counting efficiency for a given scaler sensitivity. The uncertainty involved in determining the true counting effi-



ciency applicable to the analysis of a given sample will thus be reduced.

It is recommended that a supply of a single lot of zinc sulfide be obtained which will be adequate for several months. It was found that 1 lb of zinc sulfide is sufficient for the preparation of approximately 400 scintillation flasks.

The use of a solution of silicone grease in chloroform produced a uniform coating of zinc sulfide on the walls of scintillation flasks. The silicone grease, however, is very difficult to remove when the flasks are washed, requiring special techniques and much time. A substance that could be removed with a detergent would be of definite advantage. This substance should be adhesive enough to hold the zinc sulfide and viscous enough so that it will not spread over the individual particles of zinc sulfide and intercept alpha particles.

Fritted-glass discs of uniform porosity are recommended for the fabrication of bubblers. These glass discs produced excellent diffusion of the de-emanating gas and almost complete radon removal from samples. Spring retaining clips should be used on the stopcocks on either end of the bubblers, because the rubber rings in common use may cause partial disassembly of the stopcock during transportation. Loose stopcocks will permit the leakage of water from the bubbler and are dangerous because concentrated nitric acid may also be spilled.

Some advantage might be gained, especially in the analysis of radium, if the size of the bubblers and scintillation flasks were increased. The size of the scintillation flask is the critical parameter, because above some point the counting efficiency will decrease

as a result of absorption of alpha particles in air before they can reach the walls of the flask. Doubling the size of both the bubblers and scintillation flasks would probably increase reproducibility. A simple twofold increase in the size of the bubbler and scintillation flasks would not be sufficient to make the method practical for radium analysis, as the background counting rate would also be doubled. Substitution of a radon-free de-emanating gas, however, should produce adequate results. The gas may be air that has been stored to allow radon decay or any inert gas that will remove radon from solution. The gas should have the smallest molecular weight possible to achieve the maximum effective range of the alpha particles.

### Summary

The purpose of this study was to develop a simple, reliable, and reproducible field method for the analysis of certain of the naturally occurring radioisotopes in water. The procedures were to be applied to the analysis of water supplies, particularly ground waters, during a relatively extensive field sampling program. The requirements, therefore, differed from those of many existing analytic methods in that equipment had to be compact and portable. In order to achieve significant results during a limited and expensive field survey, it was desirable that the analytic procedures be as rapid as possible without loss of accuracy.

The analytic procedure studied involved the de-emanation of Rn<sup>222</sup> from solution and the collection of the gases in an erlenmeyer flask coated with a powdered, silver-activated zinc sulfide screen, followed by alpha scintillation counting. Water samples were col-

lected in specially designed glass bubblers. De-emanation was achieved by means of an evacuated erlenmeyer flask connected to a bubbler. The vacuum was used to produce an upward flow of air through the bubbler, resulting in radon removal from the water and collection in the flask. The analysis was completed by alpha scintillation counting of the flask, with the use of a specially designed detection unit.

Ra<sup>226</sup> was also analyzed with the use of a simple modification of the de-emanation procedure. After de-emanation for radon analysis, the water sample was thoroughly purged of any remaining radon. The bubbler was then sealed for 8-12 days to allow the buildup of radon from the radium in the sample. A second radon analysis was performed on the sample, and the radium content was calculated with the use of the known state of partial equilibrium between the two radioelements.

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## Natural Radioactivity in Ground Water Supplies in Maine and New Hampshire

**Benjamin M. Smith, Werner N. Grune, Frederick B. Higgins Jr., and James G. Terrill Jr.**

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*A contribution to the Journal by Benjamin M. Smith, Graduate Research Asst.; Werner N. Grune, Prof. of Civ. Eng.; and Frederick B. Higgins Jr., Graduate Research Asst., all of San. Eng. Research Laboratories, Georgia Institute of Technology, Atlanta, Ga., and James G. Terrill Jr., Asst. Chief, Div. of Radiological Health, USPHS, Washington, D.C. The article is based on a thesis by the senior author approved in partial fulfillment of the requirements for the degree of Master of Science in Sanitary Engineering in the School of Civil Engineering, Georgia Institute of Technology, May 27, 1960.*

**A**N ever increasing interest in radioactivity and its applications has brought about the need for an assessment of human exposure to radiation. As a part of this program, it has been found necessary to examine naturally occurring radioactivity.

Although first observed in connection with certain minerals only, radioactivity has since been found to be associated with practically all minerals, rocks, and natural waters to some extent.<sup>1</sup> Of special interest is the occurrence of natural radioactivity in water. The disposal of radioactive wastes presents a potential hazard of contamination of water supplies, either ground or surface. Surface supplies may also be contaminated with fallout from nuclear explosions. The concentrations of naturally occurring radioactivity in water must be determined in order to evaluate more accurately artificial contamination. In nature, three extended series of radioactive elements exist: actinium, thorium, and uranium series. Each of these has in common a gaseous mem-

ber—a member with a very long half-life—and terminates in a stable isotope of lead.

### Occurrence of Series

Love<sup>1</sup> stated that the actinium series has not been reported as occurring in natural waters in measurable quantities. Very few data are available on the concentrations of the thorium series in water. Shimokata,<sup>2</sup> however, analyzed 53 waters in Japan and found 3 that contained concentrations of Th<sup>232</sup> in the range of 23–50  $\mu\text{g}/\text{l}$ ; the other 50 waters were found to contain no thorium activity. Foyne and others,<sup>3</sup> after examining a large number of samples, set an upper limit of 0.5  $\mu\text{g}/\text{l}$  for the thorium content of sea water. Kuroda and others<sup>4</sup> reported thoron concentrations in spring waters at Hot Springs, Ark., in the range of 300–900  $\mu\text{mC}/\text{l}$ .\* The half-lives of the members

\* Activity of 1  $\mu\text{mC}$  equals 2.22 disintegrations per minute of any radioactive substance. This disintegration rate is also defined as that of 1  $\mu\text{g}$  Ra<sup>226</sup>.

of the thorium series, other than  $\text{Th}^{232}$ , are too short to permit their accumulation either in rocks or in water.<sup>1</sup>  $\text{Ra}^{224}$  and  $\text{Ra}^{226}$ , if present in water, are usually included in values reported for the more common  $\text{Ra}^{226}$ .

The uranium series has been encountered more frequently in natural waters than the actinium and thorium series. According to the literature,<sup>1,5</sup> essentially all of the natural radio-

active daughter products of radon with short half-lives may also be found in water in equilibrium with their common parent, radon. The presence of significant amounts of natural radioactivity in a number of surface and ground waters is shown in Table 1.

### Scope of Study

The opportunity to study at first hand natural waters known to contain

TABLE 1  
Natural Radioactivity of Natural Waters

Source	Location	Uranium Activity $\mu\text{g/l}$	Radium Activity $\mu\text{mCi/l}$	Radon Activity $\mu\text{mCi/l}$	References
Mineral springs	Japan	0.002-0.95			6
Spring water	Vienna, Austria	0.36			7
Curie Spring	Boulder, Colo.		267,800	260,000	8, 9
Hot spring	Masutomi, Japan		703,000		10
Spring water	Shimane, Japan		709,800		10
Magnesium spring	Hot Springs, Va.			93,000	9
Nauheim	Glen Springs, N.Y.			26,000	9
Tiega mineral wells	Fitch, Tex.			2,000	9
White Sulphur Springs	West Virginia			860	
Pluto Spring	French Lick, Ind.			490	9
Old Orchard Mineral Spring	Missouri			430	9
Ten springs	Syria & Lebanon		7-6,150		11
Hot springs	Hot Springs, Ark.			100-30,000	4
Cold springs	Hot Springs, Ark.			100-7,300	4
Spring water	Potash Sulphur Springs, Ark.			6,000-40,000	4
Susquehanna River	Pennsylvania		0.5-1.3		12
River Thames	near Sutton, Courtney, England		0.01		13
Public water supply	Barcelona, Spain		190-480		14
Public water supply	Frankfurt, Germany		3,000-5,000		15
Public water supply	41 US cities		0-6.5		15
Drinking water	Prague, Czechoslovakia (nonsandstone)	18.9	1		7
Ground water	(deep sandstone) Illinois		1-25		16
Well & spring waters	Illinois			50-2,900	17
Deep wells	near Chicago, Ill.		5		5
Normal ground water	US, near AEC sites*		0.58-3.90		1
Normal surface water	US, near AEC sites†		0.36-3.41		1
River waters	North America	0.016-0.040	0.03		6
All river waters		1.0‡	0.07‡		18
Great Salt Lake	Utah		5		6
All sea waters		1.1-1.7			19
All sea waters			0.08‡		20

\* 25 samples.

† 15 samples.

‡ Average value.

activity of water may be attributed to radium. Usually,  $\text{U}^{238}$  and  $\text{Ra}^{226}$  are the only members of the uranium series found in water in detectable quantities. Radon, however, which is a gas and the immediate daughter product of radium, may also be present in water in detectable amounts. Further, the

detectable amounts of natural radioactivity came about in the fall of 1958, after radioactivity had been accidentally discovered in a deep well supply at Raymond, Me. In April 1959, both the New York and the New Hampshire state health departments reported similar discoveries of natural

radioactivity in ground water supplies. From a private communication to one of the authors, it was learned that in New Hampshire, "three of five domestic wells near Nottingham had a gross beta activity up to  $10^5 \mu\mu\text{C/l}$ , with appreciable quantities of alpha activity (up to  $10^4 \mu\mu\text{C/l}$ )."

The results of analyses of well waters obtained from the Raymond area indicate that uranium, radium, and radon and its daughter products are present. The reported radon activity for samples obtained from the Dielectric Products Engineering Co. in Raymond exceeded the maximum permissible concentration (MPC) almost 300 times; the same sample showed a maximum value of 1.6 times the MPC for radium.\*

In April 1958, water samples from more than 45 wells in the Raymond and Windham areas of Maine were analyzed for radioactivity by USPHS and the Maine State Health Department. The activity of radon and its daughter products was found to be 2,500–583,000  $\mu\mu\text{C/l}$ . The long-life alpha activity—primarily uranium, thorium, and radium—was found to be approximately 0–666  $\mu\mu\text{C/l}$ . It may also be noted that a radiologic survey of the geology of this area showed rather high background radiation.<sup>22</sup>

A detailed sampling program to define the occurrence and extent of natural radioactivity in ground water supplies of Maine and New Hampshire was undertaken during the summer of 1959. The program in Maine included radioassay of ground water supplies in the Raymond, Yarmouth, Rumford, and Lewiston areas. In New Hampshire, samples were collected from

areas in and around the towns of Nottingham, Northwood, Deerfield, Crafton, and Franklin. In addition, the activity in the water supply sources and in the system of Dover, N.H., a city of about 20,000 people, was studied in some detail.

After considerable experimental work, it was decided to adopt the de-emanation-scintillation method for the analysis of radon and radium. The method is similar to that used by Holaday and others<sup>23</sup> for the detection of radon in air within uranium mines. A more comprehensive discussion of the method and techniques used in this study has been reported by Higgins and others<sup>24</sup> in this issue of the JOURNAL.

### Field Data

Approximately 350 water samples were collected in Maine and New Hampshire and analyzed for  $\text{Rn}^{222}$ . Approximately 85 samples were also analyzed for  $\text{Ra}^{226}$ . Of the 350 samples for radon analysis, 304 were collected in Maine. But with duplication, this number was reduced to 234 samples for all types of water supplies, including two surface supplies. A total of 128 drilled wells and 76 dug wells were examined.

In New Hampshire, 46 samples for all types of supplies were collected. Of these, 21 samples were collected from various points of the Dover municipal supply system. Of the remaining 25 samples from New Hampshire, 17 came from drilled wells and the remainder from dug wells, a driven well, and a spring.

### Identification of Radon Activity

Two representative sampling points were selected in the Raymond area for a careful determination of the exact

\* The MPC of  $\text{Rn}^{222}$  plus daughter products is 2,000  $\mu\mu\text{C/l}$ ; of  $\text{Ra}^{226}$ , 40  $\mu\mu\text{C/l}$ .<sup>21</sup>

type of radioactivity present in the well waters. Duplicates from each sampling point, or four samples, were counted at 25 different times for a precise determination of radioisotope decay. When data collected after an initial 5-hr decay time were analyzed by the method of least squares, a decay curve of best fit was established. The data exhibited a high degree of reproducibility, as shown by a value of 0.995 for the coefficient of correlation. The equation fitted by the method of least squares is:

$$A_t = A_0 e^{-0.1798t - 0.010}$$

in which  $A_t$  is the activity of  $\text{Rn}^{222}$  at time  $t$ ;  $A_0$ , the initial activity of  $\text{Rn}^{222}$ ;  $t$ , the elapsed time in days, and  $e$ , the base of natural logarithms.

From this expression, the time required for 50 per cent of the initial

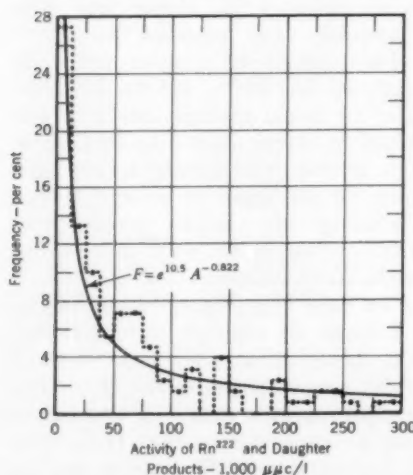


Fig. 1. Histogram and Frequency Curve for Drilled-Well Activity in Maine

Percentages are based on 128 samples, of which 123 are plotted. The activities of points not plotted were 522,000  $\mu\mu\text{c/l}$ ; 562,000  $\mu\mu\text{c/l}$ ; 579,000  $\mu\mu\text{c/l}$ ; 859,000  $\mu\mu\text{c/l}$ ; and 884,000  $\mu\mu\text{c/l}$ .

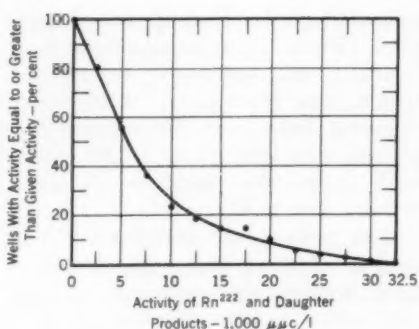


Fig. 2. Cumulative Frequency Curve for Drilled-Well Activity in Maine

As with the curve in Fig. 1, percentages are based on 128 samples, of which 123 are plotted. See italic note to Fig. 1 for activities of points not plotted.

activity to decay (half-life) was calculated to be 3.798 days. This experimental value compares quite favorably with the established half-life for  $\text{Rn}^{222}$  of 3.825 days.<sup>25</sup> The close agreement between the above values demonstrates that the gaseous radioelement determined was  $\text{Rn}^{222}$  derived from the natural uranium series.

### Distribution of Activity

A histogram of the radon \* activities from all 128 drilled wells sampled in Maine shows that 27.3 per cent of the samples were in the range of 0-12,500  $\mu\mu\text{c/l}$  (Fig. 1). Samples with activities up to 300,000  $\mu\mu\text{c/l}$  are plotted, and five additional samples with greater activities are mentioned in the italic note to the figure. Both the histogram and frequency curve, however, are based on all 128 samples.

The cumulative frequency curve for activities of radon from drilled wells in Maine is shown in Fig. 2. From

\* Unless otherwise stated, radon refers to  $\text{Rn}^{222}$  and daughter products through  $\text{Po}^{214}$ .



calculations, 99.2 per cent of the samples showed activities equal to or greater than the MPC of  $2,000 \mu\mu\text{c/l.}$ <sup>21</sup> Actually, only one sample from a drilled well was found to have an activity less than  $2,000 \mu\mu\text{c/l.}$  The generalized curve further shows that 90 per cent of all samples exceeded an activity of  $4,000 \mu\mu\text{c/l.}$ ; 50 per cent of all samples exceeded  $37,000 \mu\mu\text{c/l.}$ ; and 10 per cent of all samples exceeded  $220,000 \mu\mu\text{c/l.}$  Similarly, Fig. 2 shows that 11.5 per cent of the data exhibited an activity of 100 times the MPC.<sup>21</sup>

The activities from 76 dug wells in Maine are shown in Fig. 3. Approximately 20 per cent of the dug wells had a radon activity of  $2,500 \mu\mu\text{c/l}$  or less. The maximum activity found for the dug wells was  $31,700 \mu\mu\text{c/l.}$

The cumulative frequency curve for radon activities from dug wells (Fig.

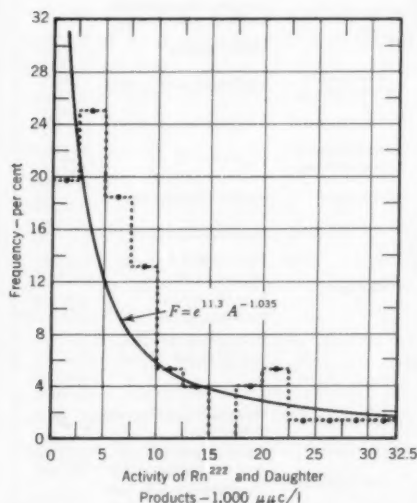


Fig. 3. Histogram and Frequency Curve for Dug-Well Activity in Maine

Percentages are based on 76 samples.

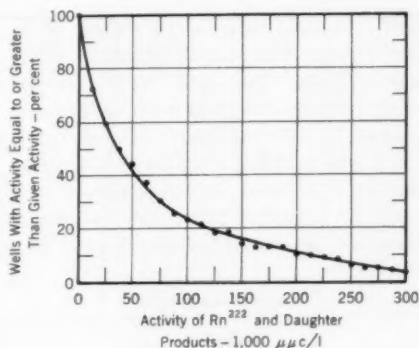


Fig. 4. Cumulative Frequency Curve for Dug-Well Activity in Maine

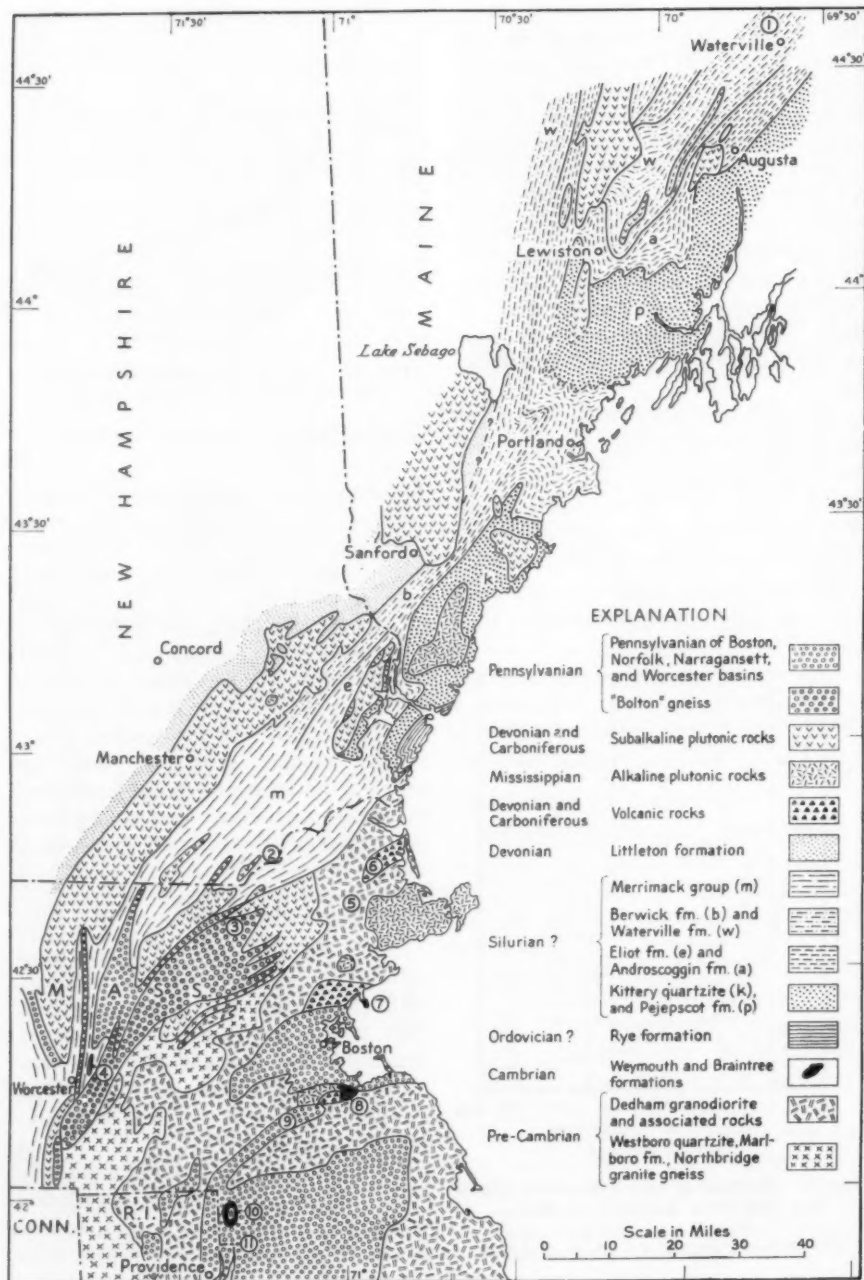
Percentages are based on 76 samples.

4) shows that approximately 84 per cent of the activity is greater than  $2,000 \mu\mu\text{c/l.}$  Figure 4 also shows that 90 per cent of all samples exceeded an activity of  $1,250 \mu\mu\text{c/l.}$ ; 50 per cent of all samples exceeded  $5,500 \mu\mu\text{c/l.}$ ; and 10 per cent of all samples exceeded  $18,500 \mu\mu\text{c/l.}$  A percentage frequency curve for all the drilled wells sampled in Maine and New Hampshire shows similar results, indicating that the radon activities of the samples obtained in Maine and New Hampshire were not significantly different from each other.

### Correlation Analyses

For a determination of a functional relationship between radon activity and well depth, selected groups of data were plotted on arithmetic graph paper and subjected to correlation analyses.

*Analyses according to states.* The results from linear correlation analyses of radon activities for Maine and New Hampshire, considered separately and combined, yielded low correlation coefficient values for all comparisons made and indicated no significant rela-



tionships between activity and depth of well.

*Analyses according to geologic zones in Maine.* In order to define the geologic boundaries of the natural radioactivity, the samples from Maine were grouped accordingly. The 2,500-sq mi area sampled was divided into four geologic zones. These four zones, G-1 to G-4, were established in accordance with the geologic map reported by Billings<sup>26</sup> (Fig. 5). The definitions of these zones are:

*Zone G-1*, the Waterville formation, is composed of calcareous and arenaceous shales, and slate with interbedded quartzite.

*Zone G-2*, the Androscoggin formation, underlies the Waterville formation. It is composed of quartzite, mica schist, phyllite, and calcareous phyllite. The combined depth of the Waterville and Androscoggin (Vassalboro) formations is 6,500 ft.

*Zone G-3*, the Pejepscot formation, is said to be a metamorphosed Kittery formation composed of gray quartzite, gray argillaceous quartzite, and gray slate. It alternates in beds varying from a few inches to several feet thick. Elsewhere, large outcrops consist of only one lithologic type.

*Zone G-4* pertains to the unknown geology of Maine due west of Zone G-1. No specific geologic information on this zone is available.

In Zone G-1 only, there appears to be a trend of increasing activity with increased depth of drilled wells. The value for the coefficient of linear correlation,  $r$ , is 0.44. Although this value

is not highly significant, it appears that some definite relationship exists between activity and well depth within Zone G-1—a relationship more definite than that existing among all drilled wells in Maine ( $r = 0.23$ ). The samples grouped under Zone G-1 include those obtained from Raymond Village and East Raymond in Maine, the area

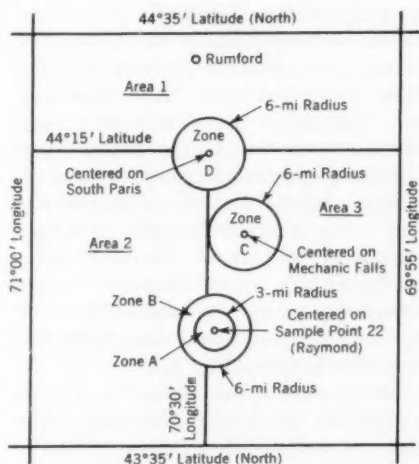


Fig. 6. Sampled Areas and Zones in Maine

Significant relationships between activity and well depth were exhibited in the zones. With the use of coordinates, areas can be located in Fig. 5.

sampled most. The equation of best fit obtained by linear correlation is:

$$A = 779D + 32,300$$

in which  $A$  is the activity of  $\text{Rn}^{222}$  and daughter products in micromicrocuries

Fig. 5. Geologic Map of Maine and New Hampshire

The map, from a study by M. P. Billings,<sup>26</sup> shows fossil localities in Massachusetts to Maine used to date certain rocks in New Hampshire. Circled numbers are fossil localities referred to by Billings. The abbreviation "fm," in the explanatory material means "formation."

per liter, and  $D$  is the depth of a drilled well in feet.

Analyses of radon activity plotted against depth of drilled wells in Zones G-2 and G-3 revealed that, in both instances, the activity decreased as depth increased. The coefficients of linear correlations for these zones are not significant.

*Analyses according to geographic zones in Maine.* Sampling points had to be selected largely on a random basis, as no complete geologic map for Maine was available. The emphasis was placed on areas that had been previously studied by the Maine State Health Department or on areas containing definite clusters of pegmatites and other mineral deposits or larger centers of population. Further correlation efforts were directed toward comparing radon activity with depth of drilled wells based on geographic zones in Maine (Fig. 6).

Within the zones shown in Fig. 6, significant relationships between activity and well depth tend to be exhibited. It was noted, however, that in Zone B, activity decreased with depth.

A further breakdown of the sampled area of Maine into three rather broad areas, excluding the zones discussed above, is also shown in Fig. 6. Little additional information could be obtained from plotting activity against depth for each of these areas. No correlation between activity and well depth was indicated.

As the area used as a basis for comparison was reduced in size, the degree of correlation improved. Figure 7 shows radon activity plotted against drilled depth for the communities of Raymond Village and East Raymond, Me. The equation of best fit relating activity with depth is:

$$A = 1,810D - 79,000.$$

The coefficient of linear correlation with a value of 0.80 was found to be significant. It should be pointed out, however, that one sample was omitted from this analysis because of doubt as to the validity of depth data.

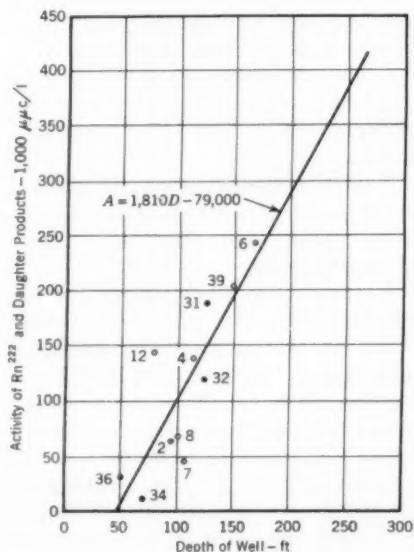


Fig. 7. Relationship Between Activity and Depth of Drilled Wells

Solid circles represent samples from East Raymond, Me.; open circles, samples from Raymond Village, Me. Sample numbers are shown near circles. Sample 33 (not shown in the figure), taken from a well depth of approximately 75 ft (exact depth could not be established) and having an activity of approximately 525,000  $\mu\text{c/l}$ , was not included in the correlation analysis.

*Analyses according to geologic zones in New Hampshire.* Similar analyses were performed with the data from drilled wells within and outside the Fitchburg Pluton rock formation in New Hampshire (subalkaline plutonic rocks, as shown in Fig. 5). The data

from samples obtained within this geologic formation showed decreased activities with increased depth. The coefficient of correlation of 0.77 is significant. On the other hand, the plot of data from samples obtained outside the Fitchburg Pluton showed increased activity with increased depth. The coefficient of correlation of 0.79 is also significant. In both instances (within and outside the Fitchburg Pluton), a significant relationship between activity and depth existed, but no real explanation can be offered for the difference between relationships.

*Results of Analyses of  $Ra^{226}$  in Maine and New Hampshire.* A correlation analysis of samples from 28 drilled wells in Maine, showing the activity of  $Ra^{226}$  plotted against depth, resulted in a value of  $r$  equal to 0.11, which is not significant. The correlation of  $Ra^{226}$  activity with depth from ten drilled wells in New Hampshire was considerably better, with an  $r$  value of 0.64; activity decreased with increased well depth.

### Other Statistical Tests

In addition to the correlation analyses described, further statistical tests were carried out in accordance with the breakdown of the 2,500-sq mi area in Maine into zones and areas and into geologic Zones G-1 to G-4, as previously defined.

*Zones and areas in Maine.* With the use of Student's  $t$  distribution and  $t$  test for significance,<sup>27</sup> it was found that if the 90 per cent level of significance is adopted, a significant difference exists between the following areas and zones, with the first of each pair having the greater average activity, as may be seen from Table 2: Zone A and Zone D; Zone A and Area 1; Zone A and Area 3; Zones A and B

and Area 1; Zones A and B and Area 3; Zone C and Area 1; Zone D and Area 1; Area 2 and Area 1; and Area 3 and Area 1. The other combinations of zones and areas were not found to be significant.

As an alternate method, an analysis of variance using the  $F$  test<sup>28</sup> was performed to compare the activities of the zones and areas. Although the  $F$  test is less effective than the  $t$  test for the analysis of extremely skewed data of this type, its results compared favorably with those of the  $t$  test, thus adding strength to the  $t$  test results.

*Comparison of geologic zones in Maine.* Further tests for statistical significance were based on the available geologic information on Maine. Significant differences in average activities were found to exist between Zone G-1 and Zone G-3, Zone G-1 and Zone G-4, and Zones G-1 and G-2 and Zones G-3 and G-4. Borderline significance was found to exist between Zone G-1 and Zone G-2. All other comparisons between geologic zones in Maine yielded results that were not significant.

In addition to these tests for significance, the chi-square distribution<sup>27</sup> was applied to test the data. The conclusions reached were quite similar to those obtained with the  $t$  and  $F$  tests, and confirm the significant differences between Zones G-1 and G-3 and between Zones G-1 and G-4.

Comparisons by statistical methods of the activities of drilled wells in granitic rocks and those in metamorphic rocks in Maine show borderline significance. A description of these geologic formations is given by Cameron and others.<sup>29</sup>

*Dug and drilled wells in Maine.* The results from statistical analyses indicate a significant difference be-





between the concentration of radon in samples from drilled wells in Maine and in those from drilled wells in New Hampshire. This result does not, however, preclude the occurrence of areas with significantly high radon activities in both states, an occurrence previously shown to exist.

A *t* test comparing the activities of drilled wells from NH-1 and Zone G-1 with those from all other geologic zones (including NH-2, G-2, G-3, and G-4) showed that the average difference in the well activities is expected to occur as a result of chance alone less than 0.1 per cent of the time. This indicates that a high level of activity may be associated with a relatively narrow formation following the outline of the Fitchburg Pluton in New Hampshire and Zone G-1 in Maine, as activities from this zone were greater than those from the other areas.

*Activity distribution based on quadrant analysis.* To obtain a better understanding of the geographic distribution of radon activity, the area in Maine was divided into small  $5 \times 5$ -min quadrants. The number of samples per 5-min quadrant and the average activity level per quadrant for drilled wells in Maine were recorded. Contours separating granitic and metamorphic rocks, according to a generalized geologic map,<sup>20</sup> were superimposed on the quadrants. It was interesting to note that all five of the areas containing the highest average concentrations are within the granitic rock formation. Four of the five areas are within Zones G-1 and G-2, previously shown to contain significantly high concentrations of activity. The sample in the fifth area had an activity of 562,000  $\mu\mu\text{c/l}$  and was obtained from the plutonic formation extending

into Maine from New Hampshire. A similar treatment of dug wells in the same area yielded more scattered results, less applicable to generalizations.

*Equilibrium between  $\text{Rn}^{222}$  and  $\text{Ra}^{226}$ .* Table 3 shows average concentrations of radium and radon in samples from those drilled and dug wells for which both analyses were available. As shown in the table,  $\text{Rn}^{222}$  activity was found to be greatly in excess of its  $\text{Ra}^{226}$  equilibrium value. The high values of the radon-radium ratio shown for Maine and New Hampshire are not unusual and have been reported elsewhere by others.<sup>15</sup>

TABLE 3  
Concentrations of  $\text{Rn}^{222}$  and  $\text{Ra}^{226}$  in Wells

State	Type of Well	Number of Wells	Avg $\text{Rn}^{222}$ Activity $\mu\mu\text{c/l}$	Avg $\text{Ra}^{226}$ Activity $\mu\mu\text{c/l}$	Activity Ratio $\text{Rn/Ra}$
Maine	drilled	33	17,100	66	259
Maine	dug	19	14,700	73	201
New Hampshire	drilled	12	32,100	6.9	4,650
New Hampshire	dug	3	5,990	4.1	1,460

### Dover Supply System

At Dover, N.H., samples were collected from five of six ground water sources and from the surface water source. Results of the analyses from 21 samples show that the maximum radon activity observed was 9,350  $\mu\mu\text{c/l}$ , compared to a MPC in water of 2,000  $\mu\mu\text{c/l}$ .<sup>21</sup> Water with a radon activity of 8,090  $\mu\mu\text{c/l}$  was passed through ferro-sand filters and aerated. When the water was discharged, it had an activity of 1,950  $\mu\mu\text{c/l}$ . This result indicates that treatment reduces the radon content of the water by 77 per cent. Similarly, the aerators for the surface supply effect a reduction in radon activity of 68 per cent. Two

water samples taken near the center of the distribution system exhibited activities of 864 and 398  $\mu\text{C}/\text{l}$ .

The maximum concentration of  $\text{Ra}^{226}$  found in the Dover water supply was 3.9  $\mu\text{C}/\text{l}$ . This activity before treatment is only about one-tenth of the MPC in water (40  $\mu\text{C}/\text{l}$ ).<sup>21</sup> It seems that the Dover population is served with water that contains little  $\text{Ra}^{226}$  and that the concentration of  $\text{Rn}^{222}$ , although almost as much as four times the MPC at some of its sources, is reduced to well within the allowable concentration by conventional water treatment practices.

### Radon Removal Studies

During the course of the sampling program, the need for a relatively inexpensive method for removing radon from private water supplies became apparent. In an effort to determine a good removal technique, several field tests were conducted. Methods now in use in many homes, as well as equipment used in water treatment plants, were subjected to tests.

As radon is a gas, it may be removed from water by aeration or by temperature elevation. The first technique, that of aeration, is the one employed in the determination of radon as was used in this sampling. In an attempt to adapt the removal methods for use in private homes, three common household devices and procedures were investigated: a faucet aerator, a faucet spray,\* and boiling the water. The removal efficiencies obtained from this limited investigation were: with the faucet aerator, 48–56 per cent; with the faucet spray, 17–18 per cent; and with boiling (for 1–5 min),

95–100 per cent. With the wooden-slot aerators located at the Dover plant, the removal efficiency was 77 per cent. With the wooden-trough spray-type aerators at the same plant, the efficiency was 68 per cent.

Although good removal efficiencies were observed with some of the methods, two important problems concerning human exposure still remain. Even if 100 per cent removal of radon from water were achieved, only about one-fifth of the total alpha and beta activity of  $\text{Rn}^{222}$  and daughter products would be removed. The remaining activity comes from the nongaseous

TABLE 4

*Radon Activity at Dielectric Co. Before and After Semi-idleness*

Day	Date—1959	Activity of $\text{Rn}^{222}$ and Daughter Products $\mu\text{C}/\text{l}$	Radioactivity on Monday With Respect to Previous Saturday %
Saturday	Aug. 8	768,000	
Monday	Aug. 10	1,150,000	149
Saturday	Aug. 15	864,000	
Monday	Aug. 17	1,120,000	139

daughter products of radon. The effective half-life of these daughter products is only about 36 min; therefore, essentially all of the major activity will decay within a period of about 6 hr.

The other problem is exposure to airborne radioactivity. This may pose a hazard unless provision is made for the safe dispersal of the removed radon.

### Variation of Activity With Pumping

The experimental data and the correlations of activity with well depth show that information about another variable, duration or rate of ground

\* Faucet Queen, made by Faucet Queens Co., Chicago, Ill.

water extraction, would be of great value in the interpretation of exposure concentrations. To observe the effect of duration of pumping on radon activity, a test was performed at a water pumping station at Paris Hill, Me.

The initial radon activity was found to be less than one-half the 5-hr activity. The 15-min activity was found to be approximately 125 per cent of the final 5-hr activity. The activity over the final hours of the test was observed to vary with time, in a range of average radon activity of 70,700  $\mu\text{c}/\text{l}$  at 1 hr to an average activity of 67,900  $\mu\text{c}/\text{l}$  at 5 hr after time zero.

Similar results were observed at the Dielectric Co. As the company does not operate from noon on Saturday to 7 AM on Monday of each week, the well is not used on weekends, except for washing purposes at four company-owned houses. Samples were collected at noon Saturday and at about 7 AM on Monday during two consecutive weekends. The results obtained are shown in Table 4.

As may be seen from the table, the activity of the well water is lower at the end of the work week than at the end of the 1.5 days of limited pumping. This variation was expected because of the interpretation of the results of the pumping test conducted at Paris Hill.

### Conclusions

These conclusions are drawn from the study:

1. The experimental value of 3.798 days for the half-life of the gaseous radioactivity encountered in ground waters of Maine and New Hampshire shows that the activity was from  $\text{Rn}^{222}$ , which has a half-life of 3.825 days. But the nature of the analytic method used does not preclude the existence

of other gaseous radioactive isotopes in these ground waters.

2. In Maine, 99.2 per cent of all the water samples from drilled wells and 84 per cent of all those from dug wells contained concentrations of  $\text{Rn}^{222}$  and daughter products exceeding 2,000  $\mu\text{c}/\text{l}$ .

3. The frequency distributions and average activities of radon in Maine and New Hampshire were not significantly different.

4. For large areas, the depth of a well did not significantly influence the radon activity of well water. But when the area used as a basis for comparison was reduced in size to only a few square miles, radon activity was found to vary linearly with depth.

5. In New Hampshire, the  $\text{Ra}^{226}$  activity decreased with increased depth; in Maine, a trend could not be established.

6. The average radon activities of drilled and dug wells in several geographic and geologic zones were found to be statistically different.

7. In Maine, drilled wells contained significantly greater concentrations of radon than did dug wells.

8. There appears to be a continuing high level of radon activity associated with the drilled wells within a relatively narrow band of geologic formations following the general outline of the Fitchburg Pluton in New Hampshire and the Waterville Formation in Maine.

9. Limited studies on the variation of radon activity with pumping time showed that radon activity varied with the duration of pumping and the idle period between pumpings.

10. In both Maine and New Hampshire,  $\text{Rn}^{222}$  was found to be in excess of equilibrium with the  $\text{Ra}^{226}$  present in the ground waters.

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## Nature and Control of Radioactive Wastes in Pennsylvania Waters

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Walter A. Lyon

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*A paper presented on Jun. 15, 1960, at the Pennsylvania Section Meeting, Pittsburgh, Pa., by Walter A. Lyon, Director, Div. of San. Eng., Pennsylvania Dept. of Health, Harrisburg, Pa.*

**P**ROBABLY no contaminant of the environment has caused so much public concern and discussion as radioactivity. Although there certainly is much reason for concern, all too frequently the size and implications of the problem are seriously misunderstood. The Pennsylvania Department of Health is presently studying the nature of radioactivity in waters in the state and is attempting to control the radioactivity that may be discharged into these waters.

### Sources of Radioactivity

Radioactivity is a pollutant only in a relative sense, because it exists everywhere in the environment. It is found naturally in soils. All natural waters contain some dissolved radioactive materials that are leached from uranium- or thorium-bearing ores present in varying amounts throughout the earth's crust. On the average, a volume of earth 1 sq mi in area and 1 ft deep contains about 18 tons of thorium and 6 tons of uranium. Such a volume of earth will contain approximately 50 curies of radioactivity.<sup>1</sup> Thorium and uranium are radioactive and yield such radioactive daughter products as radium and radon. There are more than 50 naturally occurring radioisotopes, including such familiar ones as  $K^{40}$  and  $C^{14}$ . Ground and sur-

face waters leach these radioactive materials from the earth, and they appear in water as background radioactivity.

Since the development of nuclear fission and the testing of atomic and hydrogen bombs, increasing amounts of radioactive dusts have been dispersed into the earth's atmosphere. These dusts fall out or are rained out after the tests. It is this radioactivity that, during the past few years, has raised very significantly the levels of radioactivity in Pennsylvania waters. With the increasing use of radioactive materials for the production of power and for industrial, medical, and research purposes, increasing amounts of radioactive wastes have been discharged into streams. Figure 1 shows the estimated ranges of radioactivity from various sources found in Pennsylvania streams during 1958-60. The greatest amount of radioactivity found in the streams during the past few years was a result of fallout from nuclear tests.

Except for the atomic bomb tests conducted by the French government in North Africa, no known nuclear tests have been made since the middle of 1959. The biologic effects of radiation are cumulative. If the detonation of nuclear devices is not resumed, the cumulative effect of fallout on the 30-year-old adult is not great when com-

pared with other sources of radiation. This is shown in Table 1, which is based on total radiation exposure, not on radioactivity limited to waters, as is Fig. 1. The permissible dose shown in Table 1 is in addition to medical and background doses.

### Radioactivity in Streams

The levels of gross beta activity found in three Pennsylvania streams during the past few years are shown in Fig. 2-4. In each instance, a reduction in activity occurred during 1960. Data for only the first 3 months of 1960 are reported, but the cessation of nuclear testing is clearly reflected in the lowered amounts of radioactivity found in the streams.

The maximum level of beta activity of unknown isotopes, as recommended by the National Committee on Radiation Protection (NCRP) for consumption by the general public, is 10  $\mu\text{C}/\text{l}$  of water in excess of natural

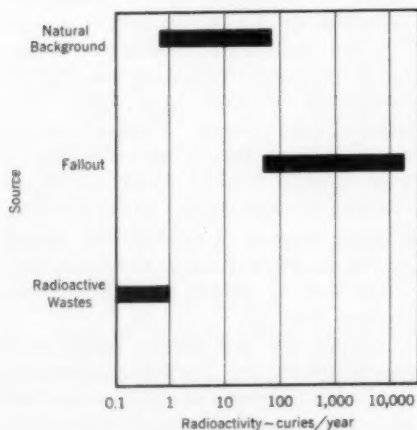


Fig. 1. Sources of Radioactivity in Pennsylvania Waters, 1958-60

*The greatest amount of radioactivity found in the waters during the past few years was a result of fallout from nuclear tests.*

TABLE 1  
Cumulative Radiation Dosages in the United States

Source	Dosage After 30 Years
Background radiation	3
Fallout radiation*	0.3
Medical radiation to gonads	3
Max. permissible radiation dose to entire population†	5

\* If nuclear weapons tests are not resumed.

† In addition to medical and background doses.

background radiation. The maximum level acceptable for occupational exposure is ten times as high, or 100  $\mu\text{C}/\text{l}$ . The fact that at various times the amounts of beta activity found in Pennsylvania streams have exceeded the recommended maximum level for the general population need not necessarily be of concern, because the NCRP recommendations are based on the assumption that all the radiation is coming from the most hazardous isotopes, such as radium and strontium. Although the Pennsylvania health department has not tested specific samples for radium or strontium, other groups, including USPHS, have. Their studies indicate that the amounts of these two isotopes in Pennsylvania waters have not exceeded the level considered safe by NCRP.

Figure 5 shows a comparison between levels of radioactivity found in surface waters in the United States during 1958 and those found in Pennsylvania streams. In general, the activity levels in Pennsylvania streams are lower than those in rivers in the western part of the United States. This condition probably exists because of the fewer naturally occurring radioactive ores found in the East and because the testing of nuclear weapons has taken place in the West.



### Radioactive Discharges

One way to control radioactivity is by controlling direct discharges to streams. The basic responsibility for controlling the use of radioactive materials other than radium is at the federal level, vested in AEC under the Atomic Energy Act. AEC licenses the users of radioactive materials and issues separate licenses for the construction and operation of reactors. Another function of AEC is the promotion of the use of radioactive materials. The USPHS Surgeon General's National Advisory Committee on Radiation (NACR) recognized in its 1959 report the conflicts of interests that exist among the vested responsibilities of AEC. NACR recommended that responsibility for primary radiation protection be established in USPHS, at the federal level, and that as much responsibility as possible be vested in state and local units of government.

In accordance with the traditional responsibility of the states to protect public health and control water pollution, Pennsylvania has assumed its share of the responsibility in insuring that harmful amounts of radioactive

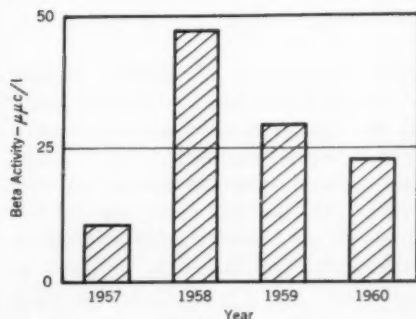


Fig. 2. Radioactivity in Ohio River

The 1960 data are for the first 3 months of the year.

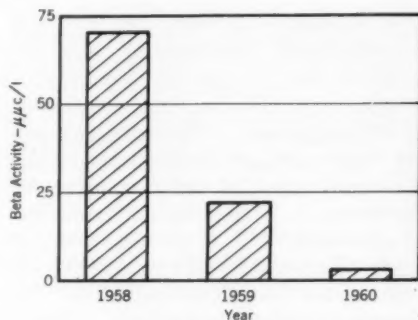


Fig. 3. Radioactivity in Tributary of Susquehanna River

The activity shown pertains to a tributary of the west branch of the Susquehanna River. The 1960 data are for the first 3 months of the year.

material are not permitted to emanate from radiation sources. The Pennsylvania Sanitary Water Board considers radioactive wastes to be industrial wastes; thus, it requires a permit for discharge of any such wastes to the waters of the state. In order to apply for such a permit, appropriate supporting engineering plans and specifications are required, and a careful staff review by the department's engineers and physicists is provided to insure that only safe levels of radioactivity are permitted in streams. As soon as the department is advised of a proposed discharge of radioactive wastes, it requires that the applicant conduct a preoperational monitoring survey at the proposed point of discharge and in the surrounding area in order to obtain reliable data on the radiation levels that prevail.

When applications for radioactive discharges are reviewed, one-tenth of the maximum permissible concentrations (MPC's) established by NCRP<sup>1a</sup> for water for a 168-hr week and for unidentified radionuclides is used. This means that for any unknown mix-

ture of isotopes, the discharge may not exceed natural background radiation by more than  $10^{-8}$   $\mu\text{c}/\text{ml}$ . This corresponds to the lifetime permissible level in drinking water. Where the isotopes are known and are readily measurable, the concentration of radioactivity in the discharge is limited to one-tenth the apportioned MPC's of the isotopes being discharged. The MPC's are apportioned in accordance with the amount of each isotope present. Where the latter standard is used, the permit-

charge. The volume of the discharge is normally limited to a fraction of the "ordinary low flow" of the receiving stream. The ordinary low flow is the average of the 90 lowest daily mean flows for a "normal" year.

Limitations on discharge were established by considerations of: (1) present and proposed uses of the stream, particularly where public water supplies and bathing places are involved; (2) present and probable future uses of the stream for radioactive

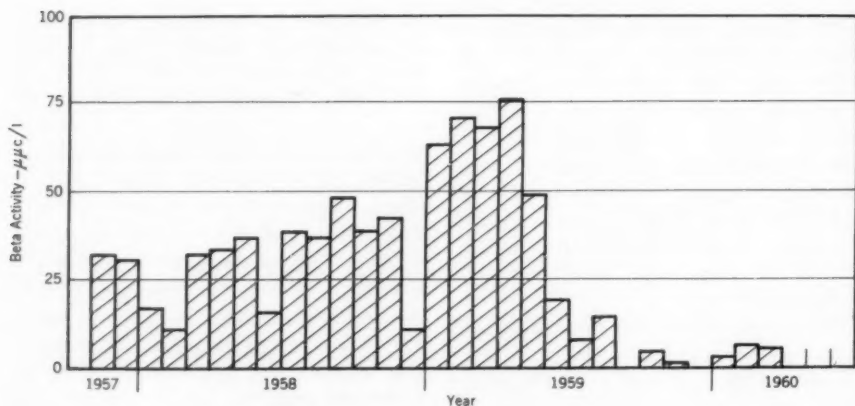


Fig. 4. Radioactivity in Delaware River

Bars pertain to monthly activity. The cessation of nuclear testing is reflected by the reduced activity during the first 3 months of 1960. No data were available for the other months of 1960.

tee must demonstrate that he can, by means of laboratory analysis or another method, establish positively the amount of each individual isotope being discharged.

After a limit has been set for the concentration of radioactivity in the discharge, the next question usually concerns the amount of the streamflow that the permittee may use in the plant to dilute wastes (in addition to other uses) in order to reach the required concentration level at the point of dis-

charge; (3) safety, dictated by the fact that knowledge in relation to the uptake of low levels of radioactivity by stream bed, bottom muds, and aquatic biota is limited at this time; (4) the fact that the NCRP limits do not consider other avenues by which the population is exposed to radiation; and (5) the fact that these limits apply only to the radioactivity added by the permittee in excess of what is already in the stream. It is believed that these limitations are fur-

ther justified because knowledge of the effect of low levels of radiation on humans is still very limited.

Consideration of these five points is tempered by the fact that the whole concept of MPC's of radioactivity in the environment is based on the premise that these levels are not to be considered design loads but guides, and in practice the least practicable amount of activity is the goal. In this regard, a statement from a recent report<sup>2</sup> and recommendations for the guidance of

sis of a linear relation between biological effect and the amount of dose, determines our basic approach to the formulation of radiation protection guides.

The lack of adequate scientific information makes it urgent that additional research be undertaken and new data developed to provide a firmer basis for evaluating biological risk. Appropriate member agencies of the Federal Radiation Council are sponsoring and encouraging research in these areas.

When an application for a permit to discharge radioactive wastes from a re-

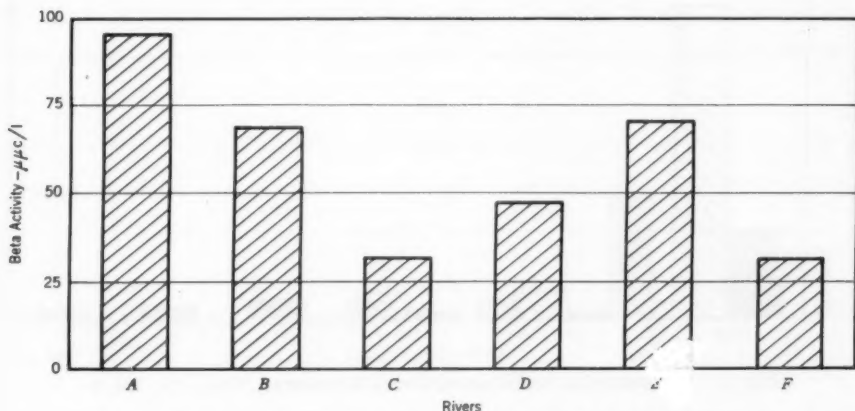


Fig. 5. Radioactivity of Surface Waters in the United States—1958

The letters beneath the bars represent: A, all rivers in the United States; B, all rivers in the United States excluding the Colorado River; C, North Atlantic rivers; D, Ohio River; E, tributary to west branch of Susquehanna River; and F, Delaware River.

federal agencies by the Federal Radiation Council are of interest:

**Basic biological assumptions.** There are insufficient data to provide a firm basis for evaluating radiation effects for all types and levels of irradiation. There is particular uncertainty with respect to the biological effects at very low doses and low-dose rates. It is not prudent therefore to assume that there is a level of radiation exposure below which there is absolute certainty that no effect may occur. This consideration, in addition to the adoption of the conservative hypothe-

actor is reviewed with regard to accident hazards, careful consideration is given to the findings and recommendations of the Advisory Committee on Reactor Safeguards. In the future, the applicant's proposal for cleanup procedures in case of contained accidents will also be reviewed. One experience in Pennsylvania has shown that such procedures, if not carefully planned, may result in the discharge of wastes in excess of permissible levels. A break in a temporary pipeline being

used during cleanup operations after an accident with a reactor in western Pennsylvania would have caused such a discharge. If it were not for quick-thinking employees, who scooped up soil with their hands and constructed an earthen dam to contain the wastes as they flowed along the ground towards a stream, a slug of wastes would have escaped.

Once an application satisfies the sanitary water board's requirements

the effect of the discharges from the Shippingport reactor on aquatic life in the Ohio River. So far the results of this work have shown significant increases in radioactivity attributable to fallout, not to radioactive waste discharges from the reactor.<sup>3</sup>

### Discharges to Sewerage Systems

Of course, not all liquid radioactive wastes are discharged directly to streams. In many communities in

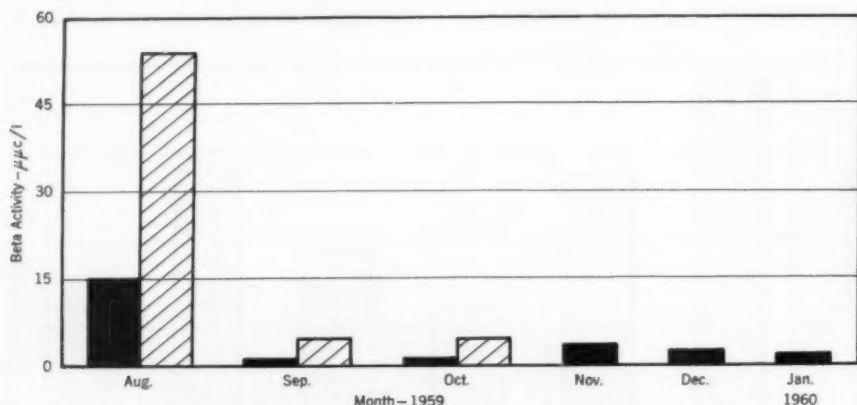


Fig. 6. Radioactivity at Filters of South Pittsburgh Water Co. Plant

*Solid bars represent activity in raw water; striped bars, in treated water. The high activity of August treated water may have been the result of a misrepresentative sample, an analytic error, or activity of chemicals used in the plant.*

and a permit is issued, it is the responsibility of the permittee and the health department to see that the standards are adhered to. As far as the permittee is concerned, he is required to submit regular operational reports concerning the wastes discharged, and the department makes inspections and analyzes waste samples in order to ascertain that the requirements are being met.

For several years, the health department has supported research at the University of Pittsburgh to determine

Pennsylvania, radioactive materials are used in buildings that discharge to public sewerage systems. With the best calculations made so far, it seems that in all instances sewerage systems provide sufficient dilution of radioactive wastes to produce a safe concentration when the sewage arrives at the treatment plant. Nevertheless, the health department is developing a program of carefully checking on the practices used in situations where radioactive materials might be discharged to sewerage systems. This will be done

by the department's Division of Sanitary Engineering in close cooperation with the Division of Occupational Health, which has the responsibility of insuring that isotopes are used safely so that no hazards to the general public or to employees may occur.

### Control of Burial

With the increasing use of radioactive materials in industries, universities, and hospitals, the volume of solid radioactive wastes that has to be buried is steadily increasing. AEC has, in the past, assumed the responsibility

ate burial grounds for radioactive materials. At present, this does not appear to be a serious problem. Nevertheless, the department is working on regulations, policies, and procedures that will govern its responsibility in this area. There is no doubt that intermediate-level radioactive wastes should be buried only on government-owned property, because knowledge and steps necessary to protect land users against hazards may not continue with changes in ownership. At present, it is contemplated that low-level wastes that can be clearly established

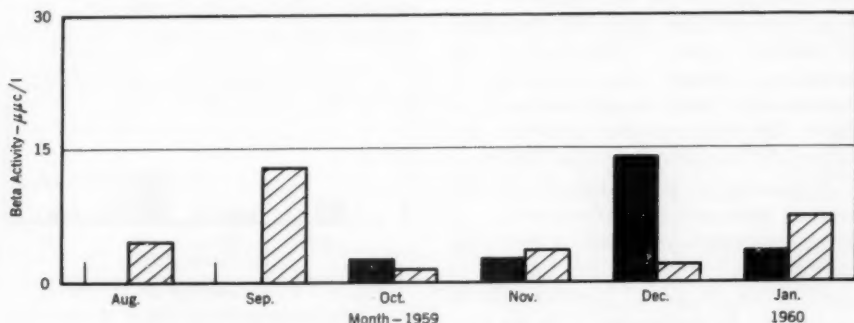


Fig. 7. Radioactivity at Filters of Westview Plant

*Solid bars represent activity in raw water; striped bars, in treated water. No activity was found in the raw water during August and September.*

for the burial of intermediate-level and high-level wastes. This is normally done at AEC facilities. But it is becoming increasingly urgent that general control over the burial of radioactive materials be provided by the state. As a result of this need, the State General Assembly, on recommendation by the health department, passed Acts 302 and 480 during the 1959 session. Act 302 empowers the department to require permits for, and otherwise regulate the burial of, radioactive wastes. Act 480 permits the state to acquire land in order to oper-

as being such (as defined by Part 20 of the AEC regulations<sup>4</sup>) may be buried on the property of the isotope user as long as appropriate reports are sent to the department.

### Radioactivity in Water Supplies

During the summer of 1959, the Division of Sanitary Engineering initiated a program of sampling sixteen typical Pennsylvania water supply facilities in order to determine the levels of radioactivity found in raw and finished waters. The sixteen facilities were selected on the basis of geo-

graphic distribution, source of water, and type of treatment. Some impounded sources, streamside sources, and ground water sources were included in the program. Some plants provide for filtration; others, chlorination only. Figures 6-8 show the results at the South Pittsburgh Water Co., Borough of Westview, and Wilkesburg-Penn Joint Water Authority plants, respectively. Generally speaking, the data indicated that activity in the water was well below the maximum levels recommended by NCRP. In part, the results were undoubtedly due to the fact that the sampling was initiated after the cessation of nuclear tests. Nevertheless, as mentioned before, the exceeding of radioactivity limits is not necessarily a cause for concern, but analyses for individual isotopes should be made.

A number of discussions in the literature concern the effectiveness of water treatment processes in removing radioactivity.<sup>5-10</sup> Because one or a number of chemical constituents in water may be radioactive, it is not possible to draw general conclusions concerning the effectiveness of specific conventional water treatment methods for removing radioactivity. The effectiveness of a method depends to a large extent on the quality of the water being treated. For example, it has been found that while nuclear testing is occurring, the radioactivity in Pennsylvania waters is associated both with dissolved and suspended solids. Sedimentation, coagulation, and filtration are effective in the removal of suspended solids and therefore will remove a great deal of radioactivity associated with suspended solids. These treatment methods, however, are not usually known to remove a great deal of dissolved solids; therefore the radio-

activity associated with dissolved solids is not reduced greatly. One exception to this rule is lime softening of water. Because of the chemical similarity between strontium and calcium, thorough lime softening will remove a high percentage of  $\text{Sr}^{90}$  contamination. The two most effective means of removing radioactivity from water is by the use of ion exchange and distillation. With these two methods, 99.99 per cent of the radioactivity can be removed.

### Future Plans and Problems

The Pennsylvania program of assessing radioactivity levels and controlling radioactive wastes is still in

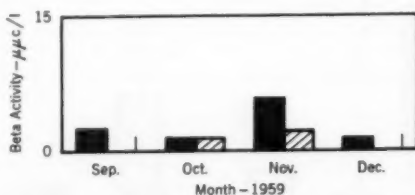


Fig. 8. Radioactivity at Filters of Wilkesburg-Penn Joint Water Authority Plant

*Solid bars represent activity in raw water; striped bars, in treated water. No activity was found in either water during August or in the treated water during September and December.*

the developmental stage. During 1961, it is hoped that a statewide stream-sampling network of approximately 150 stations will be established. Analyses for radioactivity will be among those performed on the samples collected in this network. USPHS is continuing to expand its national water quality network, and Philadelphia has, for some time, been making analyses of radioactivity found in the water it uses.



A number of philosophical problems still have not been completely resolved by society. These problems relate to the desirability of the increased use of radioactive materials if such use results in increasing levels of radioactivity in the environment. Radioactivity, like many of the newer environmental contaminants, does not suddenly reach a level acutely harmful to humans. The effects of low levels of radioactivity on humans are cumulative, and knowledge regarding these effects is still distinctly limited. Technicians in the water supply field have a responsibility to take part in these discussions, but they also have a clear responsibility to continually assess the problem and make their knowledge available to the public.

### Acknowledgments

Particular thanks are due Donald A. Lazarchik and Bernard V. Pannone, both of the Division of Sanitary Engineering, Pennsylvania Department of Health, who assisted by assembling the basic data for this article. Thanks are also expressed to the operators who collected the plant samples reported for Pennsylvania, and to the personnel of the laboratory of the Division of Occupational Health, Pennsylvania Department of Health, who analyzed the samples.

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## Automatic Fluoride Distillation

Ervin Bellack

*A contribution to the Journal by Ervin Bellack, Chemist, Div. of Dental Public Health and Resources, USPHS, Washington, D.C.*

**D**ISTILLATION of water samples prior to fluoride analysis, although often a necessary procedure, has remained a disagreeable laboratory operation. The time consumed, the potential hazard, and the unreliability of results have been contributing factors toward making the operation objectionable. With the recent modifications in the distillation method, some of the objections have been overcome, but the procedure still is not entirely foolproof.<sup>1-6</sup>

### Direct Distillation Method

The direct distillation method, however, lends itself readily to automation, and thus even routine water samples can be distilled without appreciable effort on the part of the analyst.<sup>7</sup> In this method, a sulfuric acid mixture is prepared by mixing 400 ml of distilled water with 200 ml of concentrated sulfuric acid and distilling until a temperature of 180°C is reached. Sample distillation is accomplished by adding a 300-ml sample to the mixture and again distilling to the same endpoint.

### Automatic Operation

Basically, as the distillation is completed when the temperature of the reaction mixture reaches 180°C, conversion to automatic operation requires only that a thermoregulator replace the thermometer. The thermoregu-

lator can then be used to activate the necessary mechanism to shut off the heat when the correct temperature is reached. The simplest arrangement would utilize an electric heater, controlled through a relay. Gas heat could also be used if the gas supply were interrupted by a solenoid valve or solenoid-operated pinch clamp. Further refinements are required,

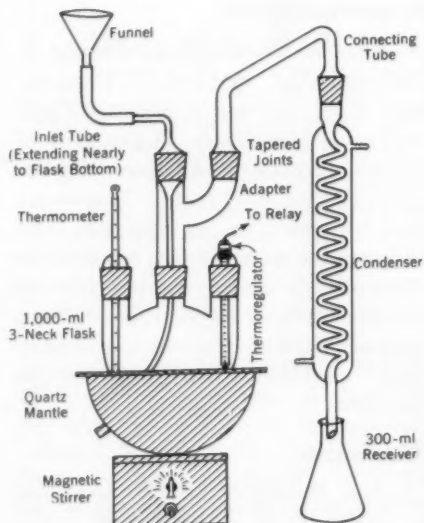


Fig. 1. Distillation Apparatus

*The setup shown provides for mixing the sample and acid, and makes possible the addition of the sample without dismantling the apparatus.*

however, to eliminate the necessity for mixing the sample and acid, and also to make possible the addition of the sample without dismantling the apparatus. These refinements have been incorporated in the apparatus shown in Fig. 1. It consists of a 1-liter, round-bottom, three-neck flask; Claisen adapter; funnel; inlet tube; connecting tube; and condenser. Heat is supplied by a quartz mantle, and the entire assembly rests on a magnetic stirrer. The mantle is controlled by a thermoregulator and a system of relays. When the push-button switch is depressed, initiating the distillation,

moregulator to cut off at about 180°C. It may be necessary to set the thermoregulator several degrees lower than 180°C because of the lag in the heating mantle. In any event, the distillation should cease when the flask contents reach 180°C. Add a 300-ml sample through the inlet funnel, press the push-button switch, and the distillation will proceed without further attention. Before the distillation is begun, the condenser water must, of course, be turned on and the magnetic stirrer adjusted to provide a slow, steady mix. Subsequent distillations require only that the sample be added and the push-

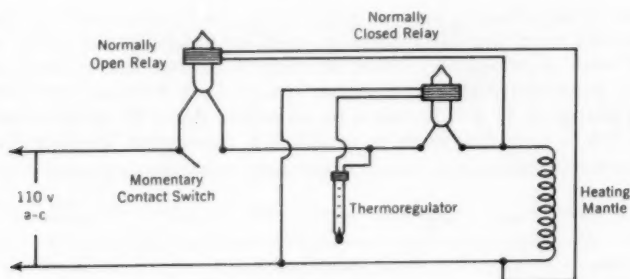


Fig. 2. Control Circuit

*This electrical circuit automatically stops the distillation after it is completed.*

heat is applied until the temperature reaches 180°C, and is then turned off automatically. The same relays also control the magnetic stirrer. The control circuit is shown in Fig. 2.

### Procedure

Prepare the flask exactly as stated in *Standard Methods*,<sup>8</sup> but substitute a glass or plastic-covered \* stirring bar for the glass beads. Adjust the ther-

button switch depressed. If visible or audible notice of distillation completion is required, a pilot light or buzzer can very easily be added to the circuit.

### Results

As the apparatus and procedure remain essentially that of the original method, accuracy, precision, and precautions are essentially the same. Because of the uniform heating characteristics of the electric mantle, however, the dangers of sulfate carryover are minimized.

\*The stirring bar was covered with Teflon, made by E. I. du Pont de Nemours & Co., Wilmington, Del.

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**AWWA B701-60**

**American Water Works Association**

**AWWA STANDARD**  
*for*  
**SODIUM FLUORIDE**

This "Standard for Sodium Fluoride" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of its use in any water treatment plant must be subjected to review by the chemist or engineer responsible for operations in the locality concerned.

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AWWA B701-60

## **AWWA Standard for Sodium Fluoride**

### **Part A—Material**

#### **Sec. 1A—Scope**

This standard covers sodium fluoride for use in the treatment of municipal and industrial water supplies. The standard is intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

#### **Sec. 2A—Definition**

Sodium fluoride is a white, crystalline powder of varying bulk density depending on its intended use. Sodium fluoride may be colored blue for identification when required. The coloring material shall be nontoxic and of a type approved by the Federal Food and Drug Administration\* and shall not exceed 0.20 per cent of the sodium fluoride by weight. Each package or container of sodium fluoride supplied under this standard shall be labeled in accordance with the provisions of Sec. 4B (Marking).

\*Food grade colors shall be used where required by state or local regulations.

#### **Sec. 3A—Caution**

Sodium fluoride dust is toxic. Men handling this material should wear protective clothing, respirators and goggles. They should be given detailed safety instructions. All equipment for handling sodium fluoride, such as storage bunkers, weigh hoppers and dry-feed machines, should be provided with devices to keep the dust hazard at a minimum.

#### **Sec. 4A—Sampling**

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

#### **Sec. 5A—Methods of Testing**

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

#### **Sec. 6A—Impurities**

The sodium fluoride supplied under this standard shall contain not more than 0.040 per cent "heavy metals" expressed as lead (Pb) and no other



soluble mineral or organic substances in quantities capable of producing deleterious or injurious effect upon the health of those consuming water that has been treated properly with sodium fluoride.

#### **Sec. 7A—Rejection**

7A.1. Notice of dissatisfaction with a shipment, based on this standard, must be in the hands of the consignor within 10 days after receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of notice of the complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples. In the event that the results obtained by the consignor, on retesting, do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded, unopened, for analysis to a laboratory agreed upon by both parties. The results of the referee analysis shall be accepted as final and the cost of the referee analysis shall be paid for by the party whose results show the greatest discrepancy from the referee results.

7A2. On the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee or a price adjustment may be agreed upon by the consignor and consignee.

### **Part B—Sampling, Inspection, Packing, and Marking**

#### **Sec. 1B—Scope**

These procedures for the sampling, inspection, packing, weighing, and marking of sodium fluoride are intended for use in connection with Part A (Material) and Part C (Testing Methods) of this document.

#### **Sec. 8A—Size**

The sodium fluoride supplied under this standard shall be a fine, dry powder containing no lumps; shall be "free flowing" from the shipping container after 30 days' storage in a clean, dry place or when stored in closed hopper bins; shall be suitable for feeding with a conventional dry-feed machine as used in water treatment; and shall be readily wetted by water.

#### **Sec. 9A—Insoluble Matter**

The insoluble matter shall not exceed 0.6 per cent.

#### **Sec. 10A—Moisture**

Moisture shall not exceed 0.5 per cent.

#### **Sec. 11A—Fluoride**

The sodium fluoride shall have a minimum of 42.9 per cent fluoride (F), which corresponds to approximately 95 per cent sodium fluoride (NaF).

#### **Sec. 12A—Data to Be Furnished by the Manufacturer**

The manufacturer shall, when requested, furnish the purchaser with a sworn affidavit stating that the material conforms in all details with the requirements of this standard. The manufacturer shall also furnish, when requested, a certified copy of the analysis of each shipment, or of the lot from which the shipment was made.

#### **Sec. 2B—Sampling**

2B.1. Samples shall be taken at the point of destination.

2B.2. If the sodium fluoride is handled by conveyor or elevator, a mechanical sampling arrangement may be used.

2B.3. If the material is packaged, 5 per cent of the packages shall be sampled. No sample for testing shall be taken from a broken package.

2B.4. Sodium fluoride may be sampled by the use of a sampling tube which is at least  $\frac{3}{4}$  in. in diameter.

2B.5. The gross sample, weighing at least 16 lb, shall be mixed thoroughly and quartered to provide three 1-lb samples. These shall be sealed in airtight, moistureproof glass containers. Each sample container shall be labeled to identify it and the label shall be signed by the sampler.

### **Sec. 3B—Packing and Shipping**

3B.1. Sodium fluoride may be shipped in multiwalled paper bags of 100 lb each, in fiber drums of 125, 375, and 400 lb each, and in barrels containing 375 lb net, each.

3B.2. The net weight of packages shall not deviate from the recorded weight by more than 2.5 per cent. If exception is taken to the weight of the

material received, it shall be based on a certified unit weight of not less than 10 per cent of the packages shipped, selected at random from the entire shipment.

### **Sec. 4B—Marking**

Each package or container of sodium fluoride supplied under this standard shall be identified by means of a red band (minimum width 3 in.) all the way around its midsection, shall bear a warning label worded:

**WARNING! POISONOUS IF INHALED OR SWALLOWED.** Avoid breathing dust. Wash thoroughly after handling. Clean up spillage immediately. Wear respirator and goggles when handling in powdered form.

and shall have an antidote printed on the label. Each package or container shall have legibly marked on it the net weight of the contents, the name of the manufacturer, and a brand name, if any, and shall bear such other markings as are required by applicable laws.

## **Part C—Testing Methods**

### **Sec. 1C—Scope**

These methods for the examination of sodium fluoride are intended for use in connection with Part A (Material) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

### **Sec. 2C—Sampling**

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. The sample delivered to the laboratory shall be quartered to approximately 100 g. After thorough mixing, this sample should be stored in an airtight glass container and

weighed out of it rapidly to avoid change in moisture content.

2C.3. The laboratory examination of the sample shall be completed within five working days after receipt of the shipment.

### **Sec. 3C—Insoluble Matter**

#### **3C.1—Procedure:**

3C.1.1. Weigh 5 g of the sample that has been previously ground to minus 100 mesh and dried for 2 hr at 105°C, or until constant weight has been reached. Dissolve in about 400 ml of hot distilled water. Digest with frequent stirring at a temperature of about 90°C for 4 hr, maintaining the

original water level by frequent additions of hot distilled water.

3C.1.2. Filter through a tared Gooch crucible, transfer the insoluble matter carefully to the crucible, and wash with at least six separate 25-ml portions of boiling distilled water, allowing the crucible to drain between washings. Continue washing until the washings no longer test positively for fluoride.

#### 3C.2—Calculation:

$$\frac{\text{Weight of residue}}{\text{Weight of sample}} \times 100 \\ = \text{per cent insoluble matter}$$

### Sec. 4C—Moisture

4C.1. *Procedure.* Weigh 5 g of the sample into a broad weighing bottle and heat in an oven at 105°C for 2 hr, or until constant weight is reached. Cool in a desiccator.

#### 4C.2—Calculation:

$$\frac{\text{Loss in weight}}{\text{Weight of sample}} \times 100 = \text{per cent moisture}$$

### Sec. 5C—Fluoride

#### 5C.1—Reagents:

(a) alcoholic potassium chloride (dissolve 60 g of potassium chloride in 400 ml of freshly boiled and cooled distilled water and add 400 ml of neutral 95 per cent ethyl alcohol)

(b) 0.200N sodium hydroxide

(c) powdered silica gel

(d) concentrated hydrochloric acid

(e) methyl orange indicator, 0.5 per cent

(f) phenolphthalein indicator, 1 per cent

(g) potassium chloride crystals

(h) ethyl alcohol, neutral.

#### 5C.2—Procedure:

5C2.1. Weigh 0.5 g of sample that has been previously ground to minus 100 mesh and dried for 2 hr at 105°C, or until constant weight is reached, into a small beaker and add 20–25 ml

of distilled water. Add 0.5 g of silica gel, a few drops of methyl orange indicator, and concentrated hydrochloric acid, dropwise, to a permanent pink color, and then 0.5 ml in excess.

5C.2.2. Bring the solution just to boiling, cool to room temperature and add 4.0 g of potassium chloride and stir until dissolved, or place on a shaking machine for at least 30 min. Add 25 ml of neutral ethyl alcohol and allow to stand for 1 hr.

5C.2.3. Filter with suction and wash with alcoholic potassium chloride solution until one washing does not destroy the color made by one drop of 0.200N sodium hydroxide solution and phenolphthalein indicator.

5C.2.4. Transfer the residue and filter paper to a 400-ml beaker; add 200 ml of recently boiled distilled water and 1–2 ml of 1 per cent phenolphthalein indicator, heat, and titrate with 0.200N sodium hydroxide. Finish titration with the solution boiling actively.

#### 5C.2.5—Calculation:

$$\frac{\text{ml of 0.200N NaOH} \times 0.0057}{\text{Weight of sample}} \times 100 \\ = \text{per cent fluoride (F)}$$

### Sec. 6C—Fluosilicate \*

#### 6C.1—Reagents:

(a) potassium nitrate, saturated solution

(b) phenolphthalein indicator, 1 per cent

\* The use of these sections is at the discretion of the purchaser. The high sodium fluoride purity (95 per cent) required by these specifications makes the application of these sections a matter of judgment. Where these impurities may affect the quality of the water supplied to the consumer to the extent that they cause consumer complaints or produce a water that does not meet the current USPHS Drinking Water Standards, they should certainly be considered.

(c) 0.100N sodium hydroxide.

**6C.2. Procedure.** Dissolve 2 g of sample that has been previously dried for 2 hr at 105°C, or until a constant weight is reached, in 40 ml of distilled water in a platinum dish and add 10 ml of a saturated solution of potassium nitrate. Cool the solution to 0°C and add three drops of 1 per cent phenolphthalein indicator. If no color appears, the solution is acid. If a pink color appears, the solution is alkaline. Neutralize the solution by adding acid or alkali until the addition barely colors phenolphthalein pink, if the solution is acid, or until the pink color just disappears, if the solution is alkaline. After adjustment, heat the solution to boiling and titrate while actively boiling with 0.100N sodium hydroxide until a permanent pink color is obtained. Not more than 1.5 ml of the 0.100N sodium hydroxide should be required (1.5 ml of 0.100N sodium hydroxide is equivalent to 0.35 per cent  $\text{Na}_2\text{SiF}_6$ ).

### Sec. 7C—Heavy Metals \*

#### 7C.1—Reagents:

- (a) concentrated hydrochloric acid
- (b) ammonium hydroxide, 10 per cent
- (c) 0.100N hydrochloric acid
- (d) hydrogen sulfide, saturated solution
- (e) lead nitrate, cp.

**7C.2. Procedure.** Treat 2 g of sample that has been previously dried for 2 hr at 105°C, or until constant weight is reached, in a platinum dish with 10 ml of concentrated hydrochloric acid and evaporate to dryness. Repeat with another 10 ml of concentrated hydrochloric acid and dilute to 40 ml with

distilled water. Measure out 20 ml of this solution into a 250-ml erlenmeyer flask and neutralize with 10 per cent ammonium hydroxide. Add 1.0 ml of 0.1N hydrochloric acid and 10 ml of a freshly prepared saturated solution of hydrogen sulfide in distilled water. The brown color produced should not be greater than that formed by 0.40 mg of lead in an equal volume of distilled water containing the same quantities of the same reagents used in the test; 0.40 mg lead is equivalent to 0.040 per cent heavy metals expressed as lead (Pb).

### Sec. 8C—Iron \*

#### 8C.1—Reagents:

- (a) concentrated hydrochloric acid
- (b) ammonium thiocyanate, 8 per cent

(c) ferric ammonium sulfate, cp.

**8C.2. Procedure.** Dilute 2.5 ml of the remaining 20 ml of the solution prepared for the lead test (Sec. 7C.2) to 20 ml with distilled water. Add 2 ml of concentrated hydrochloric acid, filter if necessary, and add 3 ml of 8 per cent aqueous solution of ammonium thiocyanate. Any red color produced should be less than that produced by 0.03 mg of iron (equivalent to 0.07 per cent iron as  $\text{Fe}_2\text{O}_3$ ).

### Sec. 9C—Limitations on Impurities \*

The following limits should be placed on impurities in sodium fluoride:

Impurity	Recommended Limit per cent	Permissible Limit per cent
Insoluble Matter	0.50	0.60
Moisture	0.15	0.50
Fluosilicate	0.35	0.70
Heavy Metals (as Pb)	0.01	0.04
Iron (as $\text{Fe}_2\text{O}_3$ )	0.07	0.15
Other*	3.92	3.01

\* See footnote on preceding page.

\* See Sec. 6A (Impurities).



**AWWA B702-60**

**American Water Works Association**

**AWWA STANDARD**  
*for*  
**SODIUM SILICOFLUORIDE**

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AWWA B702-60

*AWWA Standard for*  
**Sodium Silicofluoride**

**Part A—Material**

**Sec. 1A—Scope**

This standard covers sodium silicofluoride ( $\text{Na}_2\text{SiF}_6$ ), also known as sodium fluosilicate, for use in the treatment of municipal and industrial water supplies. The standard is intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

**Sec. 2A—Definition**

Sodium silicofluoride is a white or yellowish-white, nonhygroscopic, crystalline powder containing no water of crystallization. Sodium silicofluoride may be colored blue for identification when required. The coloring material shall be nontoxic and of a type approved by the Federal Food and Drug Administration\* and shall not exceed 0.20 per cent of the sodium silicofluoride by weight. Each package or container of sodium silicofluoride supplied under this standard shall be labeled in accordance with the provisions of Sec. 4B (Marking).

\* Food grade colors shall be used where required by state or local regulations.

**Sec. 3A—Caution in Handling**

Sodium silicofluoride dust is toxic. Men handling this material should wear protective clothing, respirators, and goggles. They should be given detailed safety instructions. All equipment for handling sodium silicofluoride, such as storage bunkers, weigh hoppers, and dry-feed machines, should be provided with devices to keep the dust hazard at a minimum.

**Sec. 4A—Sampling**

Sampling shall be conducted in accordance with Part B (Sampling Inspection, Packing, and Marking) of this document.

**Sec. 5A—Method of Testing**

The laboratory examination shall be carried on in accordance with Part C (Testing Methods) of this document.

**Sec. 6A—Impurities**

The sodium silicofluoride supplied under this standard shall contain not more than 0.050 per cent "heavy metals" expressed as lead (Pb), and no other soluble mineral or organic



substances in quantities capable of producing deleterious or injurious effect upon the health of those consuming water that has been treated properly with sodium silicofluoride.

### **Sec. 7A—Rejection**

7A.1. Notice of dissatisfaction with a shipment based on this standard must be in the hands of the consignor within 10 days after receipt of the shipment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of notice of the complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples (see Sec. 2B.5). In the event that the results obtained by the consignor, on retesting, do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded unopened, for analysis, to a laboratory agreed upon by both parties. The results of the referee analysis shall be accepted as final, and the cost of the referee analysis shall be paid for by the party whose results show the greatest discrepancy from the referee results.

7A.2. On the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee, or a price adjustment may be agreed upon by the consignor and consignee.

### **Sec. 8A—Size \***

The sodium silicofluoride supplied under this standard shall be a dry granular or powder † material containing no lumps, shall be free flowing from the shipping container after 30 days' storage in a clean, dry place or when stored in closed hopper bins, and shall be suitable for feeding with a conventional dry-feed machine as used in water treatment. The use of any type of synthetic detergent as an anticaking agent shall not be permitted. The use of anticaking materials other than synthetic or wetting-agent detergents shall be permitted, provided they do not produce any interference with normal water treatment processes, such as coagulation and sedimentation, and do not impart any taste, odor, or toxicity to the water when it is treated with the normal quantity of fluoride.

### **Sec. 9A—Insoluble Matter \***

Insoluble matter shall not exceed 0.5 per cent.

### **Sec. 10A—Moisture**

Moisture shall not exceed 0.5 per cent.

### **Sec. 11A—Sodium Silicofluoride Content**

The sodium silicofluoride shall contain a minimum of 98 per cent sodium silicofluoride ( $\text{Na}_2\text{SiF}_6$ ), which corre-

\* The use of Sec. 8A and 9A is at the discretion of the purchaser. The use of anticaking materials may require the purchaser to revise this section of the standard to correspond with local requirements and suitable materials available. The specific requirements for a material that is of proper screen size for the feeding equipment being used, and which will remain "free flowing" after a definite period of storage, is a matter that should be agreed upon by both purchaser and supplier prior to shipment. Widely varying methods of feeding, solution, and

storage of fluoride compounds at the many water utilities using fluorides exclude the possibility of a firm standard on size to cover all of these characteristics. In other words, feedability appears to depend on the uniformity of size between 100 and 325 mesh (narrow size distribution) and a low moisture content.

† Owing to the difference in types of dry chemical feeders, products characterized as "fine powder" or "fine crystal" on the market should be purchased on a test basis prior to award of a long-term contract.

sponds to approximately 59.4 per cent fluorine (F).

### **Sec. 12A—Data to Be Furnished by the Manufacturer**

The manufacturer shall, when requested, furnish the purchaser with a

sworn affidavit stating that the material conforms in all details with the requirements of this standard. The manufacturer shall also furnish, when requested, a certified copy of the analysis of each shipment, or of the lot from which the shipment was made.

## **Part B—Sampling, Inspection, Packing, and Marking**

### **Sec. 1B—Scope**

These procedures for the sampling, inspection, packing, weighing, and marketing of sodium silicofluoride are intended for use in connection with Part A (Material) and Part C (Testing Methods) of this document.

### **Sec. 2B—Sampling**

2B.1. Samples shall be taken at the point of destination.

2B.2. If the sodium silicofluoride is handled by a conveyor or elevator, a mechanical sampling arrangement may be used.

2B.3. If the material is packaged, 5 per cent of the packages shall be sampled. No sample for testing shall be taken from a broken package.

2B.4. Sodium silicofluoride may be sampled by the use of a sampling tube which is at least  $\frac{3}{4}$  in. in diameter.

2B.5. The gross sample, weighing at least 16 lb, shall be mixed thoroughly and quartered to provide three 1-lb samples. These shall be sealed in airtight, moistureproof glass containers. Each sample container shall be labeled to identify it, and the label shall be signed by the sampler.

### **Sec. 3B—Packing and Shipping**

2B.1. Sodium silicofluoride may be shipped in multiwall paper bags con-

taining 100 lb net weight each; in fiber drums containing 125, 375, or 400 lb net weight each; and in barrels containing 375 lb net weight each.

3B.2. The net weight of the packages shall not deviate from the recorded weight by more than 2.5 per cent. If exception is taken to the weight of the material received, it shall be based on a certified unit weight of not less than 10 per cent of the packages shipped, selected at random from the entire shipment.

### **Sec. 4B—Marking**

Each package or container of sodium silicofluoride supplied under this standard shall be identified by means of a red band (minimum width 3 in.) all the way around its midsection, shall bear a warning label worded

**WARNING! MAY BE FATAL IF SWALLOWED.** Avoid breathing dust. Wash thoroughly after handling. Clean up spillage immediately. Wear respirator and goggles when handling in powdered form.

and shall have an antidote printed on the label. Each package or container shall have legibly marked on it the net weight of the contents, the name of the manufacturer, and a brand name, if any, and shall bear such other markings as are required by applicable laws.

## Part C—Testing Methods

### Sec. 1C—Scope

These methods for the examination of sodium silicofluoride are intended for use in connection with Part A (Material) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

### Sec. 2C—Sampling

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. The sample delivered to the laboratory shall be quartered to approximately 100 g. After thorough mixing, this sample shall be stored in an airtight glass container and weighed out rapidly to avoid change in moisture content.

2C.3. Laboratory examination of the sample shall be completed within 5 working days after receipt of the shipment.

2C.4. Samples shall be stored for at least 30 days after the date of receipt before disposal.

### Sec. 3C—Insoluble Matter

#### 3C.1—Procedure:

3C.1.1. Weigh 2 g of sample that has been previously dried for 2 hr at 105°C, or until constant weight has been reached. Dissolve in 500 ml of hot distilled water.

3C.1.2. Filter through a tared Gooch crucible or a tared fritted-glass filter of medium porosity. Transfer the insoluble matter carefully to the crucible and wash until the washings no longer give positive results to a test for fluoride. Dry the crucible or fritted-glass filter at 105°C to constant weight.

#### 3C.2—Calculation:

$$\frac{\text{Weight of residue} \times 100}{\text{Weight of sample}} = \text{per cent insoluble matter}$$

### Sec. 4C—Moisture

#### 4C.1—Procedure:

Weigh 5 g of sample into a broad weighing bottle and heat in an oven at 105°C for 2 hr, or until constant weight is reached. Cool in a desiccator and weigh.

#### 4C.2—Calculation:

$$\frac{\text{Loss in weight} \times 100}{\text{Weight of sample}} = \text{per cent moisture}$$

### Sec. 5C—Sodium Silicofluoride

#### 5C.1—Reagents:

(a) Alcoholic potassium chloride solution: dissolve 60 g potassium chloride in 400 ml of recently boiled and cooled distilled water, and add 400 ml of 95 per cent neutral ethyl alcohol.

(b) Alcoholic potassium chloride and sodium carbonate solution prepare by saturating Reagent (a) with sodium carbonate

(c) Standard sodium hydroxide solution, 0.2N, carbonate free

(d) Phenolphthalein indicator, 1 per cent.

#### 5C.2—Procedure:

5C.2.1. Weigh into a platinum dish 0.5 g of sample that has been dried to constant weight. Add rapidly, with continuous stirring, enough of Reagent (b) to insure alkalinity. The solution must not be allowed to become acid.

5C.2.2. Filter with suction and wash with Reagent (a) until the wash liquid is not alkaline to phenolphthalein.

5C.2.3. Transfer the filter and residue to a beaker and add 100 ml of

recently boiled and cooled distilled water. Heat to 70°–90°C and titrate with 0.2*N* sodium hydroxide, using phenolphthalein indicator. Continue heating and complete the titration with the solution actively boiling.

5C.3—*Calculation:* \*

$$\frac{\text{ml } 0.2N \text{ NaOH} \times 0.0094 \times 100}{\text{Weight (g) of sample}}$$

= per cent sodium silicofluoride ( $\text{Na}_2\text{SiF}_6$ )

NOTE: Because of the high degree of purity (98 per cent) required for sodium silicofluoride by this standard,

the list of limitations on impurities, together with recommended tests for them, has been omitted. If such limitations and tests are of interest, refer to Sec. 7C–9C of the Standard for Sodium Fluoride—AWWA B701. (In Sec. 9C of B701, the limitations on impurities for “Fluosilicate” and “Other” would not apply.)

\* Based on the chemical equation:

$\text{K}_2\text{SiF}_6 + 4\text{NaOH} = 2\text{KF} + 4\text{NaF} + \text{H}_4\text{SiO}_4$   
from which 1 ml 0.2*N* NaOH is equivalent to 0.0094 g  $\text{Na}_2\text{SiF}_6$ .



**AWWA B703-60**

**American Water Works Association**

## **AWWA STANDARD**

*for*

## **FLUOSILICIC ACID**

This "Standard for Fluosilicic Acid" is based upon the best known experience and is intended for use under normal conditions. It is not designed for unqualified use under all conditions, and the advisability of its use in any water treatment plant must be subjected to review by the chemist or engineer responsible for operations in the locality concerned.

First Edition approved as "Tentative" Jul. 30, 1954; Second Edition approved  
May 15, 1960.

**AMERICAN WATER WORKS ASSOCIATION**

*Incorporated*

**2 Park Avenue, New York 16, N.Y.**



AWWA B703-60

## **AWWA Standard for Fluosilicic Acid**

### **Part A—Material**

#### **Sec. 1A—Scope**

This standard covers fluosilicic acid ( $\text{H}_2\text{SiF}_6$ ) for use in the treatment of municipal and industrial water supplies. The standard is intended for use in connection with Part B (Sampling, Inspection, Packing, and Marking) and Part C (Testing Methods) of this document.

#### **Sec. 2A—Definition**

Fluosilicic acid ( $\text{H}_2\text{SiF}_6$ ) is a strong, colorless, acid liquid. The commercial acid contains 20–30 per cent  $\text{H}_2\text{SiF}_6$ . It attacks glass and stoneware and must be stored in rubber- or plastic-lined containers. It has a corrosive action on the skin.

#### **Sec. 3A—Caution**

Because of its corrosive action, fluosilicic acid should be handled with care. If it comes in contact with the skin, the part affected should be immediately washed with large volumes of clear, cool water. The material should be stored in the type of container recommended by the manufacturer.

#### **Sec. 4A—Sampling**

Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

#### **Sec. 5A—Methods of Testing**

The laboratory examination shall be carried out in accordance with Part C (Testing Methods) of this document.

#### **Sec. 6A—Impurities**

The fluosilicic acid supplied under this standard shall not contain more than 0.020 per cent “heavy metals” expressed as lead (Pb), and no other soluble mineral or organic substances in quantities capable of a deleterious or injurious effect upon the health of those consuming water that has been treated properly with fluosilicic acid.

#### **Sec. 7A—Rejection**

7A.1. Notice of dissatisfaction with a shipment based on this standard must be in the hands of the consignor within 10 days after receipt of ship-



ment at the point of destination. If the consignor desires a retest, he shall notify the consignee within 5 days of receipt of notice of the complaint. Upon receipt of the request for a retest, the consignee shall forward to the consignor one of the sealed samples taken as described in Sec. 2B.3. In the event that the results obtained by the consignor, on retesting, do not agree with the results obtained by the consignee, the other sealed sample shall be forwarded, unopened, for analysis, to a laboratory agreed upon by both parties. The results obtained by the referee shall be accepted as final and the cost of the referee analysis shall be paid by the party whose results show the greatest discrepancy from the referee analysis.

7A.2. On the basis of the retest or the referee test, the consignor may remove the material from the premises of the consignee or a price adjustment

may be agreed upon by the consignor and consignee.

### **Sec. 8A—Physical Requirements**

8A.1. The fluosilicic acid shall be from "water white" to "straw yellow" in color and shall be free from suspended matter.

### **Sec. 9A—Acid Strength**

The fluosilicic acid supplied under this standard shall contain not less than 23 per cent  $\text{H}_2\text{SiF}_6$  by weight.\*

### **Sec. 10A—Data to Be Furnished by Manufacturer**

The manufacturer shall, when requested, furnish the purchaser with a sworn affidavit stating that the material conforms in all details with the requirements of this standard. The manufacturers shall also furnish, when requested, a certified copy of the analysis of each shipment, or of the lot from which the shipment was made.

## **Part B—Sampling, Inspection, Packing, and Marking**

### **Sec. 1B—Scope**

These procedures for sampling, inspection, packing, weighing, and marking of fluosilicic acid are intended for use with Part A (Material) and Part C (Testing Methods) of this document.

### **Sec. 2B—Sampling**

2B.1. Samples shall be taken at the point of destination.

2B.2. At least 5 per cent of the containers shall be sampled.

2B.3. Before sampling, the fluosilicic acid in the containers shall be

\* A less concentrated acid may be specified, but, as the fluosilicic acid concentration may vary from 23 to 30 per cent, care should be exercised to specify a concentration known to be suitable for the feeding equipment to be used, or permissible variations in acid strength. Where variations in acid strength are acceptable, suitable arrangements should be made between the purchaser and supplier on the method of payment, either by a bonus-penalty clause or by prorating each delivery with a guaranteed price at a set acid content.

When undiluted fluosilicic acid is fed directly into water to produce a concentration of approximately 1.0 ppm, no particular difficulties are encountered. In the dilution of concentrated fluosilicic acid to the desired strength, the formation of a precipitate may be avoided by using a soft, clear water. Distilled water is preferable, although cation-exchange softened water or water with less than 25-ppm hardness will do. (Reference to an article entitled "Dilution of Fluosilicic Acid," JOURNAL AWWA, Vol. 48, No. 2, Feb. 1956, is suggested.)

mixed by rolling or other suitable means. A gross sample, with a volume of at least 2.5 qt, shall be collected in a clean plastic or rubber container. Containers lined with acid-resistant plastic, wax, or rubber may also be utilized. After mixing, three 0.5-pint samples shall be provided from the gross sample. They shall be sealed in airtight, moistureproof plastic or rubber containers. Each sample container shall be labeled to identify it and the label shall be signed by the sampler.

When sampling a tank truck or tank car, at least five different 0.5-pint portions shall be taken as a representative sample.

2B.4. Samples shall be held for 30 days before being disposed of.

### **Sec. 3B—Packing and Shipping**

3B.1. Packaging and shipping of all fluosilicic acid solutions shall conform to the current regulations of the Interstate Commerce Commission.

3B.2. Fluosilicic acid may be shipped in steel drums lined with rubber or acid-resistant plastic, in rubber- or plastic-lined cars, or in rubber- or plastic-lined tank trucks. It may also be shipped in smaller containers similarly protected.

3B.3. The net weight or net volume of the containers shall not be less than the recorded weight or volume, or more than 10 per cent greater. If exception is taken to the weight or volume of the material received, it shall be based on the certified weight or volume of not less than 10 per cent of the containers, selected at random from the entire shipment.

### **Sec. 4B—Marking**

Each shipment shall carry with it clear identification of the material and a warning of potential danger in handling. Each unit package shall have marked legibly on it the net weight or volume of the contents, the name of the manufacturer, the lot number, and the brand name, if any.

## **Part C—Testing Methods**

### **Sec. 1C—Scope**

These methods for the examination of fluosilicic acid are intended for use with Part A (Material) and Part B (Sampling, Inspection, Packing, and Marking) of this document.

### **Sec. 2C—Sampling**

2C.1. Sampling shall be conducted in accordance with Part B (Sampling, Inspection, Packing, and Marking) of this document.

2C.2. The laboratory examination of the sample shall be completed within 5 working days after receipt of shipment.

### **Sec. 3C—Fluosilicic Acid Content**

The following alternative methods for determining the percentage of fluosilicic acid may be used\*:

#### **3C.1—Specific-Gravity Method**

##### **3C1.1—Apparatus:**

(a) Acid-resistant plastic or glass cylinder or dish with sufficient depth to float hydrometer

(b) Glass hydrometer (long stem) capable of being read to four decimal places. (If the density of the solution

\* Where facilities permit, it is recommended that acid strength be determined by the method outlined in Sec. 3C.2.

varies over a wide range, a set of three or more hydrometers should be available to cover the range.)

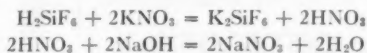
### 3C.1.2—Procedure\*:

Carefully transfer the fluosilicic acid from the sample bottle to the cylinder and adjust the temperature to 17.5°C. Insert the hydrometer and measure the specific gravity. The approximate percentage of fluosilicic acid can be determined by reading from a table or graph prepared from a number of shipment analyses in which both specific gravity and actual fluoride content have been established.

## 3C.2—Hydrogen Titration Method

### 3C.2.1—Principle:

Titration of ionizable hydrogen in a chilled solution from which the fluosilicate ions have been precipitated as potassium fluosilicate:



The titration with ice and potassium nitrate is commonly used in practice, because it closely approximates the method of evaluating the more stable

\* The hydrometer and other glassware should not be kept in contact with the fluosilicic acid solution any longer than is necessary. After using, the hydrometer and other glassware should be immediately and thoroughly rinsed in clear, cool, running water. The use of a standard table from a handbook of chemistry and physics is not recommended. These tables are prepared from dilutions of c.p. grade acid in distilled water and may introduce errors of more than 10 per cent. Experience in the field has shown that the specific gravity of commercial grades of fluosilicic acid in concentrations from 23 to 30 per cent vary considerably (5–13 per cent less than that given in a standard table) between different manufacturers, and the use of the specific-gravity method should be considered to give only a rough approximation of the actual fluoride content of the liquid material.

acids, and suffices for the usual trade purposes.

### 3C.2.2—Reagents:

- (a) Ice
- (b) Potassium nitrate, saturated solution
- (c) Sodium hydroxide solution, standard, approximately 0.5N
- (d) Bromthymol blue, 0.2 per cent solution.

### 3C.2.3—Procedure:

Pipet 25 ml of sample into a 500-ml volumetric flask. Dilute with distilled water to the mark and mix. Put a handful of clean ice into a 400-ml beaker, add 25 ml potassium nitrate solution, and pipet a 25-ml aliquot of the sample solution into the beaker. Wash down the sides of the beaker and, stirring constantly, promptly titrate with standard sodium hydroxide, using bromthymol blue as indicator. The endpoint has been reached when the blue color persists for at least 30 sec. On longer standing, the indicator will turn yellow.

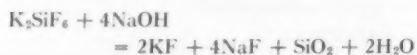
### 3C.2.4—Calculation:

$$\begin{aligned} \text{Vol. of sample} &= 25 \times \frac{25}{500} = 1.25 \text{ ml} \\ \text{Weight (g) of sample} &= 1.25 \times \text{sp gr (at room temp.)} \\ \frac{\text{ml NaOH} \times \text{normality} \times 0.072 \times 100}{\text{weight (g) of sample}} &= \% \text{H}_2\text{SiF}_6 \end{aligned}$$

## 3C.3—Determination of Free Acid

3C.3.1. It is obvious that the preceding method will include any free acid other than fluosilicic acid that may be present. If it is desired to distinguish between fluosilicic and other acids, place the beaker, whose contents have been titrated as above, on a hot plate and bring to a boil. Titrate the hot solution with the standard sodium hydroxide to the neutral point of the bromthymol blue. This titration

breaks down the fluosilicate radical of the potassium fluosilicate:



If the fluosilicic acid is 100 per cent pure, the milliliters of NaOH used in the cold titration will equal exactly half the milliliters of NaOH used in the hot titration. If free acid other than fluosilicic is present, the cold titer will exceed half the hot titer. If fluosilicate salts are present, half the hot titer will exceed the cold titer.

#### 3C.3.2—Calculation:

$$\frac{\left[ \text{ml NaOH (cold titer)} - \frac{\text{ml NaOH (hot titer)}}{2} \right] \times \text{normality} \times 0.02 \times 100}{\text{weight (g) of sample}}$$

= per cent free acid other than fluosilicic expressed as HF

$$\frac{\frac{\text{ml NaOH}}{2} (\text{hot titer}) \times \text{normality} \times 0.072 \times 100}{\text{weight (g) of sample}} = \% \text{H}_2\text{SiF}_6$$

### Sec. 4C—Heavy Metals

#### 4C.1—Reagents:

(a) ammonium hydroxide, 10 per cent

(b) 0.10N hydrochloric acid

(c) hydrogen sulfide, saturated solution

(d) lead nitrate, cp.

#### 4C.2—Procedure:

Dilute 4.0 g of sample to 40 ml with distilled water. Measure out 20 ml of this solution into a 250-ml erlenmeyer flask and neutralize to pH 7.0 with 10 per cent ammonium hydroxide. Add 1.0 ml of 0.10N hydrochloric acid and 10 ml of a freshly prepared saturated solution of hydrogen sulfide in distilled water. The brown color produced should not be greater than that ex-

hibited by 0.40 mg of lead in an equal volume of distilled water containing the same quantities of reagents used in the test; 0.40 mg of lead indicated by the test is equivalent to 0.020 per cent heavy metals expressed as lead (Pb).

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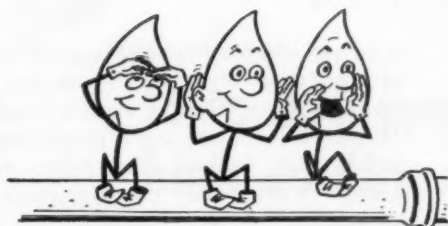
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## *Percolation and Runoff*

'All the water they need, when and where they need it' is what Californians voted for last November 8 in approving the record-breaking 1 $\frac{3}{4}$ -billion-dollar bond issue to finance the state's Feather River water development project. "All the water they need, when and where they need it" is what citizens of Denver have voted for time after time in approving multimillion dollar bond issues to bring water through the mountains from the western slopes to provide for their increasing thirst. "All the water they need, when and where they need it" is what the Lake Erie Watershed Conservation Foundation is trying to assure the 30 northern counties of Ohio by a comprehensive development plan for use of Lake Erie water. "All the water they need, when and where they need it" is what New Yorkers are paying for in continuing to develop their distant Delaware River reservoir system. And "all the water they need, when and where they need it" is what people not only throughout America, but throughout the world are becoming more and more thirsty for as standards of living rise.

There is, in other words, a "water problem" that is almost universal. But, despite the alarming prophecies and frightening headlines, the problem

is not one of "What water?" First, it is one of "Whose water?" and then of "How much will it cost to move it to where you need it when you need it?" In California, all reports would seem to indicate that the narrow margin of victory (140,000 in a total vote of more than 5,500,000) was less the result of the record-breaking amount of money involved, than concern in the well-watered northern part of the state that it would be giving up rights to water it would one day need. In Denver, too, although the cost of transmountain diversion is tremendous, it has been the right to take the water that has involved the greatest concern. And there, as in other similar projects, the question of water rights and the economics of the project have been closely interrelated. Overseas, meanwhile, the question of water rights is even more explosive as Pakistan and India have come close to blows over the waters of the Indus and the United Arab Republic has threatened war if Israel diverts more of the River Jordan water to its own uses.

That the problem is not "What water?" was emphasized further by Dr. Richard D. Hoak, head of the American Iron & Steel Institute water resources research project, in a recent

*(Continued on page 30 P&R)*

(Continued from page 29 P&R)

speech before the Technical Association of the Pulp & Paper Industry. "America has no cause to worry about a water shortage," he said, "either now or in the year 2000." And his optimism was based on the estimate that it will ultimately be economically feasible to develop 650 bgd of fresh water from the 1,220 bgd of rainfall runoff to streams in the United States, whereas present actual "consumption" (as contrasted to "use") of water totals only 72 bgd.

But if "all the water they need, when and where they need it" thereby promises to become a more difficult legal and financial problem than an engineering one, it still remains first a problem of public education, for it is the public purse and the public thirst that are involved.

**Academic**, of course, is what this whole discussion would have been if Mandrake hadn't been given the galactic alarm by Emperor Magnon of the Central Galaxy. Or were you really unaware that the water pirates in a space ship a thousand miles high were drying up our lakes and oceans with a warm attractor ray that drew water out into space where they froze it into ovoids and delivered it to the dry planets at a handsome price? Fortunately Mandrake the Magician was able to borrow a space suit and to let himself get drawn up with one of the lakes. And fortunately when he was sucked into the ship, the space men were interested enough in him to reveal themselves and thus let him press the button on his galactic alarm and call in Emperor Magnon's patrol fleet. And still more fortunately Mandrake's

technique of mass hypnosis worked on the space men "better than a stun gun" so that he was able to survive until the patrol fleet came and captured the pirates and returned the water to Earth. Or else—well, ask your youngest son. . . .

**Speaking of public education**, though, one bit of knowledge that ought in some way to be communicated to our customers if we are ever to do a real job of selling water is that our product contains no calories. Now, we have it on the authority of Dr. H. Frederick Kilander of New York University, who has been conducting general health education tests ever since 1936, one-third of the public is still convinced that water contains calories and is fattening. What we need is more statements like that of Dr. Doris Johnson of the Department of Public Health Nutrition at the Yale University School of Medicine, who says:

Water is calorie-free and therefore cannot be fattening. Many people think they should not drink water when trying to lose weight. This is one of our more dangerous fallacies, probably created because two-thirds of the total body weight is water. But the amount of water held in the body in no way changes the fat content of the individual persons. Water is essential to health at all times, and no restriction on water drinking should be practiced without careful medical supervision. In fact, when dieting, it is desirable to drink water between meals because it often will relieve hunger pangs.

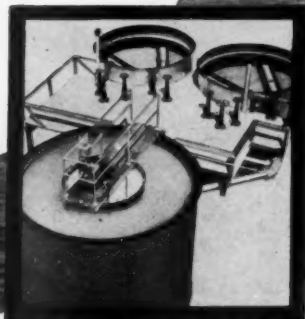
On the other hand, we suppose that some water works psychologist could be trying to trick his fine fat friends into drinking water by making it "daring." Not that many friends, though!

(Continued on page 32 P&R)

*You can have...*

# 15 to 350 gpm high quality water at low cost!

...with the  
**ACCELAPAK®**  
Treating Plant



Are you looking for a clarification or softening plant which can be installed at comparatively low cost and will produce high-quality water with very little supervision? The "ACCELAPAK" treating plant is your answer. It is specifically designed for small communities, construction camps, sub-divisions, industrial plants, resorts and estates.

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Over 3,000 "ACCELATOR" units are now in successful operation. If you are tolerating inferior water or makeshift methods of treatment, investigate the "ACCELAPAK" plant. Write today for Bulletin 1870-B.

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throughout the United  
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other countries.



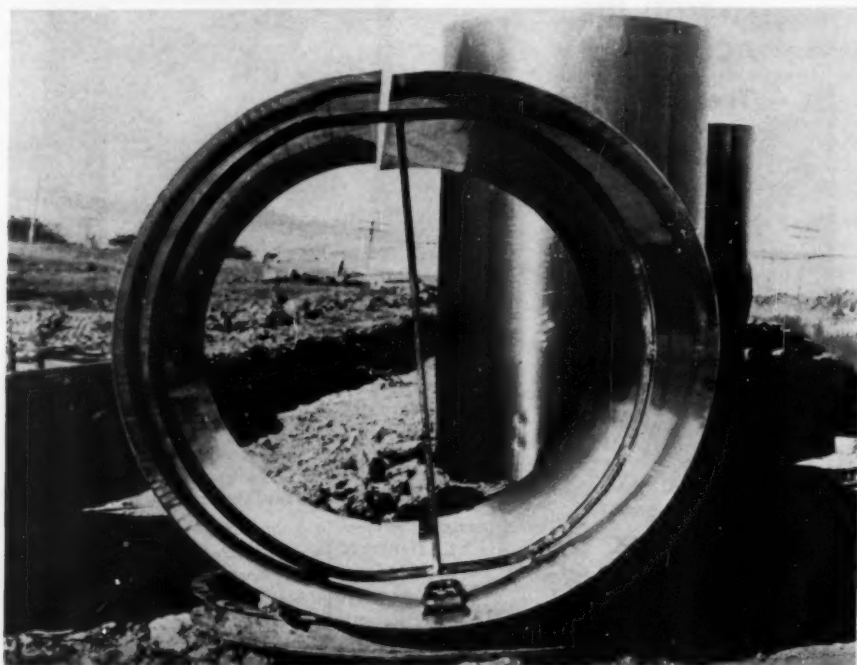
(Continued from page 30 P&R)

**Unusual reservoirs** were installed recently at Albion, Wash., and St. Petersburg, Fla.

At Albion, the reservoir consisted of a 60-in. jointless concrete pipe (see cut), extruded in place, encircling the crown of a hill above town. Built by R. A. Hanson Co., Inc., Palouse, Wash., whose self-propelled "Extruda-

placed on a concrete cradle under 30 ft of water. Presumably designed for atomic age storage, the 10,000-gal tank was produced by Firestone Tire & Rubber Co. for Jet Fuel & Storage Co. Price was \$5,000 plus installation.

**Halls of Fame** we consider as the natural habitat of AWWA presidents,



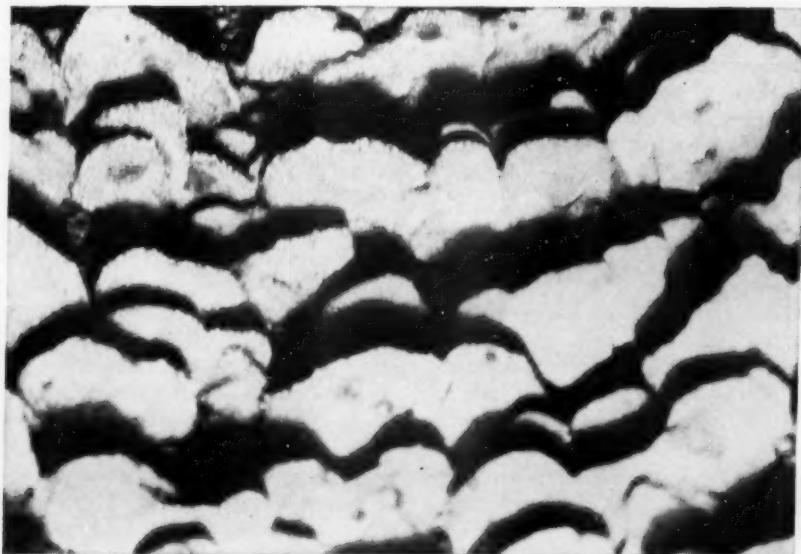
Cast" machine casts jointless pipe directly in trench excavations using the undisturbed earth of the trench as an outer form, the pipe has a smooth, full-circumference bore unbroken by joints or grouting, achieved through use of full-circle inner forms constructed of aluminum.

At St. Petersburg, Fla., the reservoir was made of rubber-coated nylon

so we are glad to take note of two more such associations:

**Morrison B. Cunningham**, superintendent of the Oklahoma City water department and president of AWWA in 1953-54, became in November the sixth member of the Oklahoma State University Engineering Hall of Fame. The honor, which is accorded each year to an outstanding Oklahoma

(Continued on page 34 P&R)



## why pump water over ? mountains like these?

The "mountains" are tubercles—from the inside of a water main—enlarged only slightly. Mountains like this are what send pumping costs skyrocketing—and reduce the effective diameter of mains and piping as much as 20%.

Tuberculation forms fast . . . in fact, it starts the moment a main is cleaned, and gets in its worst licks during the first few months after cleaning. So it makes sense to protect metal surfaces immediately after cleaning—by using Calgon® Composition TG right behind the scraper. Composition TG is remarkably fast at forming a protective film, putting a barrier between the bare metal and water. It will also help disperse the removed corrosion prod-

ucts, making it easier to flush them from the main.

Calgon Composition TG has other benefits, too, when used in continuous treatment. (1) It makes "red water" complaints a thing of the past. (2) It is especially helpful in areas of low flow, and when temperatures go up. (3) Its greater efficiency keeps chemical costs down.

A letter or phone call will bring you more information on how Calgon can help. Or, an experienced Calgon engineer will be glad to make detailed recommendations on your specific problem.

**CALGON COMPANY**  
HAGAN CENTER, PITTSBURGH 30, PA.



DIVISION OF **HAGAN** CHEMICALS & CONTROLS, INC.

(Continued from page 32 P&R)

member of the engineering profession, will place a bronze plaque carrying Past-President Cunningham's name on permanent display in the OSU engineering building.

**A. P. Black**, research professor of chemistry at the University of Florida and president of AWWA in 1949-50, has just been elected to a third 5-year term as a member of the College of Electors of the Hall of Fame for Great Americans at New York University. One of 154 electors, which include the most distinguished men and women among college executives, historians, scientists, authors, editors, artists, and public officials, Dr. Black is one of ten scientists. Serving with him in that category are Donald C. Balfour, Detlev W. Bronk, Cecil W. Creel,

C. W. Mayo, Robert Oppenheimer, Fairfield Osborn, Jonas Edward Salk, W. F. G. Swann, and J. C. Walker.

**Great to-do** was made in the newspapers recently over the fact that a computer translating Russian engineering papers into English for the National Bureau of Standards was so stupid as to translate the Russian expression for "hydraulic ram" into the English "water goat." And properly so, we would say, for isn't this proof that the machine will never replace man? Certainly it's a mistake that 95 per cent of us wouldn't make. As a matter of fact, we rather doubt we'd even recognize the language as Russian. Which leads us to wonder whose goat should be got.

(Continued on page 36 P&R)

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National Tank Maintenance Corporation as a pioneer in the field of Annual Maintenance can show you how to save money

1. Thorough inspection by qualified inspectors to determine structural, paint and rust conditions.
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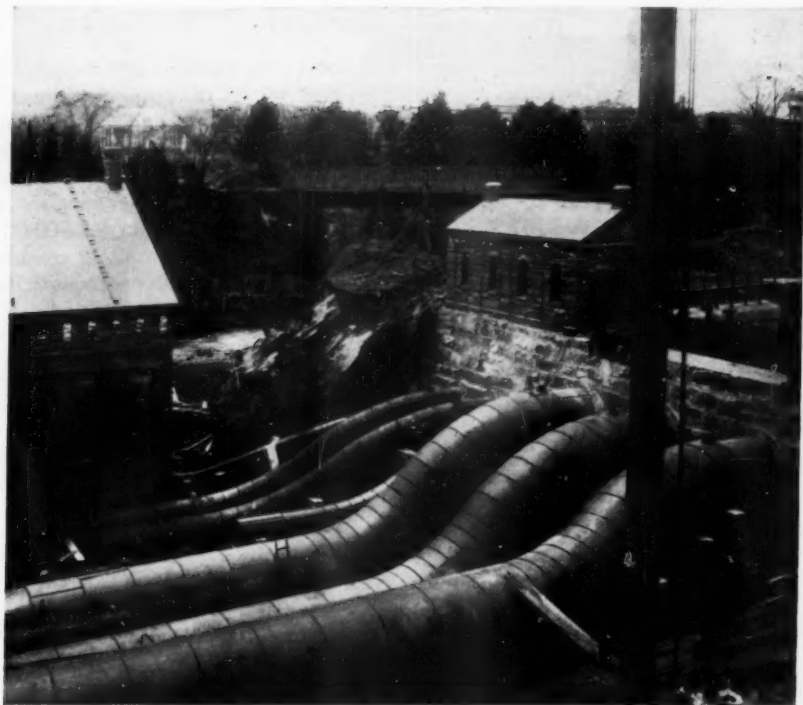


*Moving?*

Don't forget to notify us of your new address—and the sooner the better, as it takes a couple of months before a mailing list change can be made. Write to:

**Journal AWWA**  
**American Water Works Assn.**  
**2 Park Ave., New York 16, N.Y.**





## Steel pipe installed in 1899 is still on the job

OVER sixty years ago, when a predecessor of the Passaic Valley Water Commission built a pumping station at Little Falls, New Jersey, they installed the riveted steel pipe shown above. It includes three 12-ft penstocks, and one 36-in., one 48-in., and two 66-in. supply mains.

In 1903 a filtration plant (the world's first large-size rapid sand filter system) was added. Since that time the major portion of the water supply for the communities of Paterson, Passaic, and Clifton has

passed through these pipes. With time out for cleaning and re-lining two of the penstocks, the lines have been in service for over 60 years.

Beginning in 1894, over thirty miles of large-diameter steel mains have been installed in the area served by the Passaic Valley Water Commission. All are in service today.

Isn't this persuasive evidence of the long service life of steel water mains? For information about today's vastly improved steel pipe, contact our nearest sales office.



for Strength  
... Economy  
... Versatility

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Export Sales: Bethlehem Steel Export Corporation

# BETHLEHEM STEEL



(Continued from page 34 P&amp;R)

**Caries carries** is the way a profluoridationist would sum up the recent election, for proposals to fluoridate public water supplies were defeated in all cities in which they were on the ballot. In Cincinnati, the largest city involved, the defeat, by 107,782 to 83,685, was the second in 7 years, leaving \$27,000 worth of fluoridation equipment purchased in 1952 still unused. Other defeats in the November election were registered at:

Antigo, Wis. ....	2,076 to 1,473
Faribault, Minn. ....	3,073 to 2,418
Freeport, Ill. ....	6,586 to 5,203
Joplin, Mo. ....	8,251 to 6,742
Kenton County, Ky. ..	17,690 to 10,621
Mapleshade, N.J. ....	2,450 to 2,278
Marin County, Calif. ..	29,133 to 21,879
Montello, Wis. ....	293 to 258
Sacramento, Calif. ....	46,529 to 31,868
Saginaw, Mich. ....	15,632 to 11,842
Waukesha, Wis. ....	5,712 to 3,612
Weyauwega, Wis. ....	339 to 338
Willmar, Minn. ....	2,921 to 2,038

For the year as a whole the election record for fluoridation stood at a poor 13 victories in 56 attempts. Meanwhile, in other communities where elections were not involved, progress was also considerably slowed. Whereas Ladysmith, Wis., adopted fluoridation by council action as a result of a citizens' petition requesting that the decision be based upon scientific evidence, the town commission at Montclair, N.J., procrastinated in taking action on the measure recommended by its advisory health committee and the New York City Board of Estimates continued to avoid a vote for lack of support despite the favorable reports of the health and water commissioners and the support of Mayor Wagner. From Puerto Rico, meanwhile, came word that 93 per cent of the popula-

tion served by public water supplies is receiving water of optimum fluoride content compared to only 35 per cent in the United States. In the United States, as of last August, fluorides were being added to the supplies of 1,932 communities serving 37,500,000, whereas the supplies of 1,903 communities serving 7,000,000 persons naturally contained adequate fluorides.

**William B. Harman** has retired from his position as director of public utilities for Newport News, Va. A recipient of the Fuller Award in 1956, he is currently AWWA director from the Virginia Section.

**'Instant Fun—Just Add Water'** is the way that a Jacksonville, Fla., firm recently advertised its swimming pools. "Instant Swim—Just Add Water," meanwhile, was being advertised by New York's Cabana Pools, Inc., whose do-it-yourself "Convert-A-Pool" can be assembled in an afternoon and, then, can be traded in later at full list price (\$795-\$1,145) against one of Cabana's regular permanent sunken pools. More nearly instant, too, is the means which the National Swimming Pool Institute has been recommending for obtaining approval of municipal swimming pools—that is, by private financing, through sale of bonds to only those members of the community who want to use the pool. Partly by this method, it is reported, community pools have grown from 4,000 in 1948 to more than 20,000 in 1960. Now that it has gotten to the point that even *Kiplinger Magazine* (August 1960) is issuing instructions on how to buy or build a pool, it could be "Instant Problem—Just Aid Water."

(Continued on page 38 P&amp;R)

*here's what  
"out of sight  
out of mind"  
does to a  
water main*



"Out of sight—out of mind" can be a mighty expensive philosophy in any water distribution system. The above unretouched photograph proves this point. It shows a badly tuberculated eight inch main whose inside diameter was reduced to an average of almost 4.5 inches. Resultant higher pumping costs with reduced pressure and carrying capacity make it costly to tolerate such conditions. That is why the savings effected in reduced pumping costs frequently pay for the low cost of National water main cleaning.

Since there's never a charge or obligation to inspect your mains, call National now!



*Call in National today!*

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333 Candler Building, Atlanta 3, Georgia; 920 Grayson St., Berkeley, Calif.; 115 Peterboro St., Boston 15, Mass.; 533 Hollis Road, Charlotte, N. C.; 8 S. Dearborn St., Rm. 808, Chicago 3, Ill.; P. O. Box 385, Decatur, Ga.; 2024 Merced Ave., El Monte, Calif.; 315 N. Crescent St., Flandreau, South Dakota; 3707 Madison Ave., Kansas City, Missouri; 200 Lumber Exchange Bldg., Minneapolis 1, Minn.; 510 Standard Oil Bldg., Omaha 2, Nebraska; 2910 W. Clay Street, Richmond 21, Va.; 502 West 3rd South, Salt Lake City 10, Utah; 204 Slayton St., Signal Mountain, Tenn.; 424 S. Yale Avenue, Villa Park, Illinois; 7445 Chester Avenue, Montreal, Canada; 576 Wall Street, Winnipeg, Manitoba, Canada; Apartado de Correos No. 5, Bogota, Colombia; Apartado 561, Caracas, Venezuela; P. O. Box 531, Havana, Cuba; Marquinaria, Apartado 2184, San Juan 10, Puerto Rico; Bolivar 441-A, Maraf., Lima, Peru



(Continued from page 36 P&R)

'Remember the Main' is the new version of an old slogan from Cuba, and the main is the one that delivers 2.3 mgd of Yeteras River water to the Guantanamo Naval Base. Navy officials are very well aware that the main runs 4.6 mi beyond the boundaries of the base and that it will require only the shutting of a valve to cut off the supply completely. With 10 mgd of elevated storage on the base and with Navy tankers as well as desalting equipment on call, cutting off the supply would no doubt result in discomfort and inefficiency rather than destruction. Because it would probably also result in the unemployment of 3,000 Cubans now working on the base and providing the Castro government with \$125,000 per week in US funds, it is

likely that the main will remain in service with fidelity.

**Stamp out water waste** seems to be the point in the philatelic news from Israel. Thus, a feature in *Linn's Weekly Stamp News* last November was a special postal cancellation used at Tel Aviv-Yafo last July picturing a leaking faucet and the slogan: "Citizens Save Water: It Is a Command From Heaven." What surprised us even more, though, was the explanation in the *News*:

Water is very definitely a problem in hot, arid Israel, and constant research goes into the development of new resources.

At present, radioisotopes are being used to explore potential underground

(Continued on page 40 P&R)

## WHY USE TWICE THE WATER YOU NEED TO CLEAN FILTER BEDS?



H & T AIR-WATER WASH FILTERS use only half as much water as ordinary systems. Yet the air and water, together, clean the filter bed more completely!

We are the **ONLY** large, experienced manufacturer of Air-Water Wash Filters. In the past 45 years, we've made hundreds of successful installations. Get the money-saving facts about H & T AIR-WATER WASH FILTERS.



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## $A_s + A_y$ = FLEXIBLE DESIGN

When an engineer designs a complete water transportation system, he must give consideration to the differences in internal pressure caused by changes in elevation, hydraulic gradient, and many other varying operating conditions. American Concrete Cylinder Pipe offers a flexible design to accommodate these conditions through variations in the gauge of the steel cylinder, the diameter of the circumferential steel rod reinforcement, and the center-to-center spacing of the rod reinforcement to obtain the precise cross-sectional steel area required.

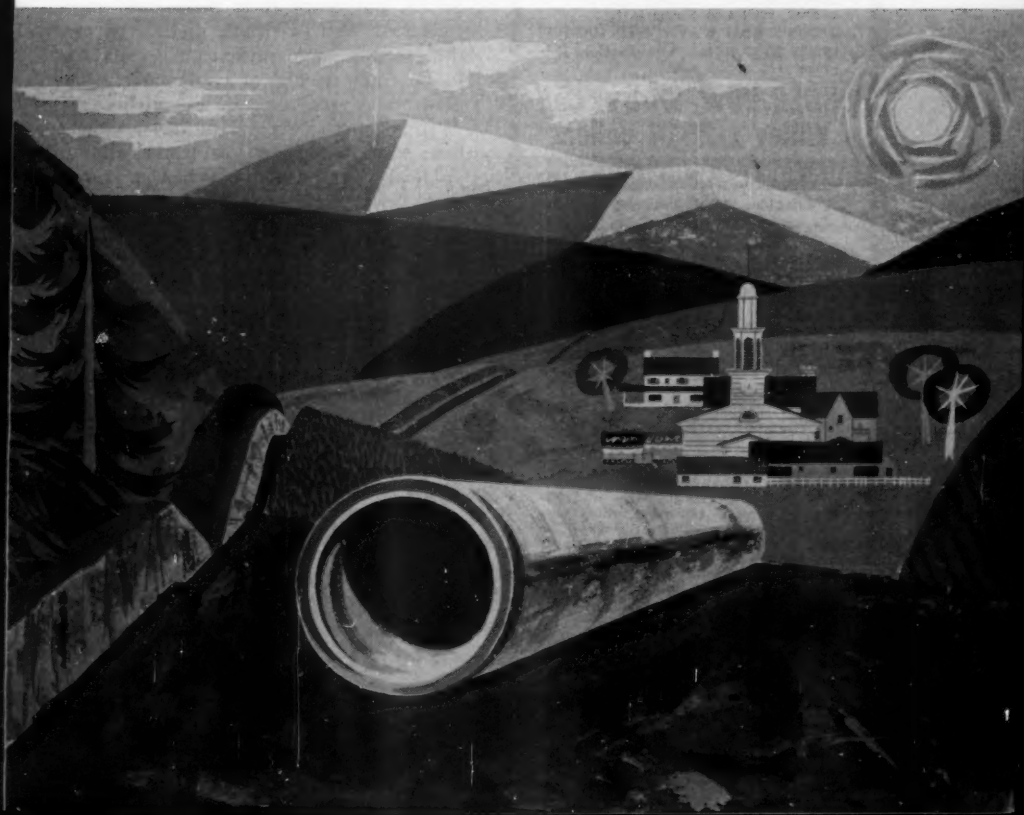
■ The cost of delivered water should be measured, not in terms of the initial investment for the system which transports it but in terms of the ultimate cost of that system. With the flexible design of American Concrete Cylinder Pipe, an engineer can obtain a system economical in ultimate cost and enduring in reliable performance.

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(Continued from page 38 P&R)

water supplies, which represent two-thirds of Israel's total water potential.

In addition, artificial rain experiments—for instance, cloud seeding—are being carried out by the National Rainfall Committee in collaboration with the Israel Water Planning Co., the Air Force, and the Meteorological Service.

We, who had always thought philately was just stamp collecting, apologize.

The Greeks have long been noted for their great culture and civilized approach to the finer things in life. But we never quite appreciated them so much as in reading in Lawrence Durrell's *Prospero's Cell*\*:

Abstemious in the matter of drinks, the Greeks produce their own light wines and cognacs in abundance. Yet during our whole stay here we have seen a drunk person not more than once; and more endearing still, we have discovered that these people have so delicate a palate as to be connoisseurs of cold water. The glass of water appears everywhere; it is an adjunct to every kind of sweetmeat, and even to alcohol. It has a kind of Biblical significance. When a Greek drinks water he *tastes* it, and, pressing it against the palate, savors it. The peasants will readily tell you which wells give the sweetest water, while even the townspeople retain a delicate taste in water, and are able to recognize the different sources from which the little white town handcars (covered in green boughs) are replenished.

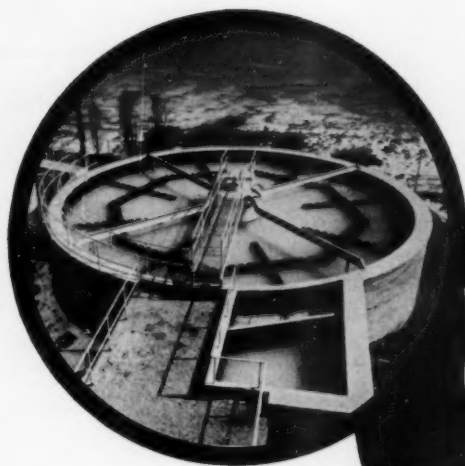
This, indeed, is the glory that was Greece!

Water pressure, exerted unsuccessfully by Toledo, Ohio, to force annexation (see August P&R, p. 42) and successfully by Louisville, Ky., to re-

\* E. P. Dutton & Co., New York.

(Continued on page 42 P&R)





## Why General Filter is EVERYWHERE

### **E**verywhere in the nation

you'll find General Filter water and waste treatment equipment giving complete satisfaction to municipalities and industries. Here's why:

**DEPENDABILITY** — the result of more than twenty years' experience in building quality water process equipment. **ECONOMY** — proved by long life and trouble-free operation of General Filter plants. **SERVICE** — by 45 sales offices and 36 field service departments coast-to-coast. There are many other reasons why it pays to specify General Filter. Write for complete information, bulletins and free estimates.

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WATER PROCESS EQUIPMENT AMES, IOWA

AERATORS • FILTERS • SOFTENERS • CLARIFIERS  
FLASH MIXERS • FLOCCULATORS • PNEUMATIC CONTROLS  
ROTARY DISTRIBUTORS • SLUDGE SCRAPERS

(Continued from page 40 P&R)

quire funding of extensions (see September P&R, p. 36), has now apparently been successfully applied by Cleveland as a means of forcing new residential developments to install sewers and sewage treatment plants. Unable to reach the suburban developments with its building and sanitary codes, the city has through its water department, on which the developments must depend for a supply, required installation of sewers and sewage treatment facilities before agreeing to supply water. Basis of the requirement is concern with the danger that wastes from such developments will find their way into Lake Erie, the source of water supply. Result has been more compact and better arranged communities, to reduce the length of sewer lines. The lines connecting the developments with the Cleveland system are, of course, called force mains.

**James B. Clow & Sons, Inc.**, is constructing a \$3,000,000 plant at Melbourne, Australia, for the manufacture of cast-iron pipe. Clow will own the plant in partnership with General Industries, Ltd., an Australian firm, under the joint corporate name of Meters-Clow Pty., Ltd.

**Frederick G. Merckel**, director and retired president of Wallace & Tiernan Inc., died in London on Oct. 29, 1960, after a short illness. He was 64 years old. Born in New York City in 1896, he graduated from Columbia University in June 1916 with a degree in civil engineering. He was then resident engineer at Erie Basin, served with Alphonse Custodis Chimney Co. on engineering and design, and then worked for the New York Continental Jewell Filter Co., prior to entering the



F. G. Merckel



A. H. Perry

Army in June 1918, where he served as a second lieutenant in the Sanitary Corps.

Joining Wallace & Tiernan in January 1921, he was assigned to the Kansas City sales office, and then sent to Shanghai to supervise the installation of a new water filtration plant. Upon his return to the United States, he was made manager of the company's office in Chicago, which position he held until 1930 when he returned to the main office. During the next 23 years, he participated in almost all of the company's operations. On Jan. 1, 1954, when Wallace & Tiernan became a publicly owned company upon merger with Novadel-Agene Corp., he was elected to the office of president, where he served until 1959.

An AWWA member since 1921, he was a Life Member. He was also a fellow of APHA and a member of the executive committee of the World Health Organization.

**Aubrey H. Perry**, regional engineer at Vancouver, B.C., for the Canadian Department of National Health & Welfare, died on Oct. 11, 1960, at Vancouver.

Born at Fort Hope, Ont., in 1906, he received his bachelor's degree in

(Continued on page 44 P&R)



## "Did I get burned by a low pump bid!"

"Sure we got a low price on our pumps — 3% lower — but we're plenty sorry we didn't write an experience clause into the specs. We've had nothing but trouble and complaints since those pumps went into operation. Sure the manufacturer is cooperative. Why shouldn't he be. He's using *us* as a guinea pig on an untested design. I can't afford to be a testing department for every 'Johnny-come-lately.' I want pumps that *work*. Next time we'll have an 'experience clause.' When it comes to buying pumps . . . one burn is too many."

*Reliability — one of the inherent qualities you get when you buy Allis-Chalmers. General Products Division, Allis-Chalmers, Milwaukee 1, Wisconsin.*

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### **ALLIS-CHALMERS — 92 YEARS OF PUMP EXPERIENCE**

Allis-Chalmers has a pump-building history going back over 90 years. In 1888, we developed the largest centrifugal pumps of that time . . . and they are still operating. Through a program of sound, gradual development, Allis-Chalmers pump designs are improved regularly with tested ideas . . . no idea goes into production for our customers until it has been proved sound in tests.

(Continued from page 42 P&amp;R)

applied science from the University of Toronto in 1930. He then joined the public health engineering division of the health department, working first at St. Catharines, Ont. In 1936, he went to Vancouver to open the district office for the department.

A member of AWWA since 1931, he was awarded the Powell-Lindsay citation by the Pacific Northwest Section in 1959. At the time of his death, he was serving the section as its chairman.

Arthur J. Simpson, engineer in charge of the Newark (N.J.) Division of Water Supply, died Nov. 26, 1960, in Newark. His age was 70. Born in Chicago, he obtained his degree in civil engineering from Cooper Union (New York City) in 1912, after which he did graduate work at Columbia University. From 1914 to 1925, he worked for the city of Newark in various engineering assignments. For three years he worked as a private consultant in Florida, but returned to Newark in 1928 as assistant engineer in the water department. He was appointed to position of chief engineer in 1952.

An AWWA member since 1952, he was also a member of the New Jersey Society of Professional Engineers.



## Employment Information

Classified ads will be accepted only for "Positions Available" or "Position Wanted." Rate: \$1.50 per line (minimum \$5.00), payable before publication. Deadline for ad copy: first of month prior to month of publication desired. To place ad, obtain "Classified Ad Authorization Form" from: Classified Ad Dept., Journal American Water Works Assn., 2 Park Ave., New York 16, N.Y.

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### Positions Available

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#### WATER RESOURCES PLANNER

Experienced engineer in water supply studies for regions or large cities and industries. Public health and waste treatment experience desirable, but not necessary. Good knowledge of cost analyses. Report writing ability necessary. Minimum of five years' experience required. Location Cincinnati; similar positions expected at Chicago and Denver. Salary \$7,560 to \$12,210 per year, depending upon qualifications. Civil service requirements and benefits apply. Write to Director, Robert A. Taft Sanitary Engineering Center, 4676 Columbia Parkway, Cincinnati 26, Ohio.

**Superintendent of Water Department, Meadville, Pennsylvania.** Population 17,000. Prefer graduate Sanitary, Civil, or Mechanical Engineer, with some experience. Salary dependent on qualifications. Present rate \$6,000. Send resume to City Engineer, City Hall, Meadville, Pennsylvania.

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THE **NEW feco**  
**LIGHTNING**  
**SURFACE**  
**WASH BAFFLES**  
for **RAPID SAND FILTERS**

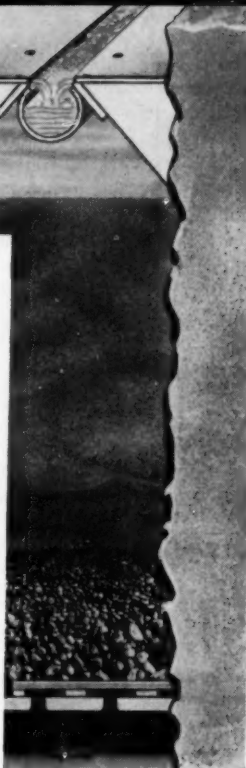
A clean filter bed in half the backwash time —made possible by the increased velocity of backwash water in cleaning area above expanded sand. Flow of water is directed to wash troughs. Foreign matter put in sewer. If filter develops uneven flow or "sand-boils," baffles deflect flow horizontally toward surface of sand in areas where vertical flow is restricted. Creates slight back pressure on filter above sand level, helping to equalize flow. Covers provide surface for precipitation of solids, reducing load on filter. Dirt can be washed off surfaces into wash troughs.



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## Correspondence

### Superdames

To the Editor:

Sigworth, Larson, Sisco and Scott's views on feminine statistics (August P&R p. 54; November P&R p. 102) and their concern about the ladies taking over AWWA are indeed insignificant compared to the prognostication of one Dr. Herman J. Muller, Hoosier geneticist (see story reprinted below). According to the good Doctor the time is approaching when not only AWWA but the entire world will be ruled by a race of Amazonian superwomen who will tolerate (?) only a sufficient number of males to stock the sperm banks.

As for myself, statistics were always somewhat dull and, as I am getting a new set of bifocals next week, I hope to continue my interest in figures rather than numbers.

N. M. DEJARNETTE

Engr., Robert & Co., Atlanta, Ga.

Dec. 5, 1960

LONDON (AP)—The British Medical Association's magazine said Thursday the time may come when a race of superwomen will rule a manless world.

"It could happen," warned the *Family Doctor*, a monthly magazine published and edited by physicians.

"Biologically speaking, there is no real need for such a large number of males in the population as we have today," wrote A. J. Burton, a biology researcher.

He quoted a 1946 Nobel Prize winner, Dr. Herman J. Muller, as saying that sperm should be taken from geniuses, frozen for 20 years, and then administered to carefully selected females to produce a race of supermen. Dr. Muller is a geneticist on the faculty of the University of Indiana.

Burton pointed to honey bees, saying a hive contains many thousands of them, but only a few are males.

The green flies banish males from their population for all but a short season of the year.

"Such a reduction in the importance of numbers of the males seems to be foreshadowed by Dr. Muller's suggestion," said the article.

"He talks of a race of supermen, but may it not be more probably a race of superwomen?"

"All that would be required in such a scientifically planned society would be a few selected males to keep up the stocks of the frozen sperm in the sperm banks.

"The world could be ruled by a race of Amazonian women, of whom only the fittest individuals would be allowed to reproduce."

*It is noted that Dr. Muller already calls himself Herman.—Ed.*

\* \* \*

### Clamor for Glamor

To the Editor:

Re Quality Water (October P&R p. 35), having sampled East Bay MUD output (water, that is) and found it excellent, Larkin could raise the price and bill for "Ne plus ultra water" (wonder how many squawks he'd get for adding something to his product).

Of course, Greenville's (S.C.) Johnny Hawkins could use "Nothing finer can be found in Carolina" for his mountain dew.

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E. L. FILBY

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**Key:** In the reference to the publication in which the abstracted article appears, 39:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is pagged by the issue, 39:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *BH*—*Bulletin of Hygiene (Great Britain)*; *CA*—*Chemical Abstracts*; *Corr.*—*Corrosion*; *IM*—*Institute of Metals (Great Britain)*; *PHEA*—*Public Health Engineering Abstracts*; *SIW*—*Sewage and Industrial Wastes*; *WPA*—*Water Pollution Abstracts (Great Britain)*.

### BOILERS AND FEEDWATER

**Some Aspects of the Chemistry of Water for a Steam Power Station.** M. BODMER. *Brown Boveri Rev.*, 45:552 ('58). Boiler feedwater has now reached such high purity that analytical methods for very dil. solns. must be used, such as flame spectrophotometry, ion exchange for concn., complexometry, chromatography for gases, and radioactive indicators. Most difficult of all is detn. of nonelectrolytic substances such as O, SiO<sub>2</sub>, H (in steam), and nondissoc. or undefined org. compds. Contamm. of water by evaporator priming or condenser leakage is noted by detg. Cl ions, possibly by flame spectrophotometry. Results for SiO<sub>2</sub> are usually too high because of impurities in reagents. For detns. of dissolved O, piston-type sampling vessel proposed by Potter has been adopted by Brown Boveri. With the precautions given by Potter, it should be possible to det. dissolved O with an accuracy of  $\pm 1\gamma/l$ . Examples show the importance of interpreting detn. of Cu. This element, being both corrosion agent and product, is an important factor when considering aggressivity of water. Data are given for concn. of Cu throughout a high-pressure steam system. Cu may act as a powerful oxidizing agent.—CA

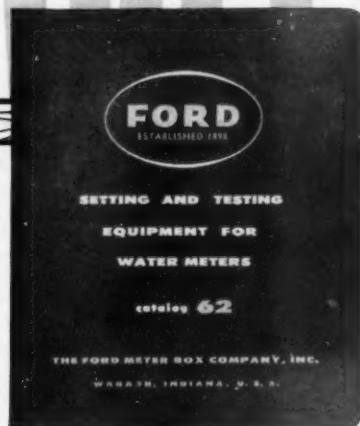
**Prevention of Corrosion and Deposits in Power Plant Boilers.** H. E. CROSSLEY. *Residential Conf. Major Develops. Liquid Fuel Firing 1948-59, Proc., Torquay, Engl.*, 1959, D8-D12 (Pub. '60). Reducing the amt. of excess O<sub>2</sub> in flue gas from about 3% to less than 1% resulted in decreasing the SO<sub>3</sub> concn. from 20 ppm to about 2-7 ppm and the dew point from 270-320°F to 240-255°F. When a boiler was operated with less than 0.6% O<sub>2</sub> in the combustion chamber, flue gases contained 5 ppm SO<sub>3</sub> and had a dew point of 180°F. When excess O<sub>2</sub> was increased to 4%, the concn. of SO<sub>3</sub> increased to 45 ppm, and the dew point increased to

320°F. The use of powd. base additives, such as dolomite and MgCO<sub>3</sub>, to react with SO<sub>3</sub> led to a decrease in the rate of corrosion, but did not prevent it completely. Tar bases, used in carefully controlled amts., may prevent corrosion of metal surfaces by an inhibiting action. NH<sub>3</sub> was not satisfactory as an additive because excessive amts. were consumed by SO<sub>3</sub>, and because (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> blocked air heaters. The use of a ZnO smoke decreased SO<sub>3</sub> concns. in flue gas to 5-10 ppm, and gave dew points of 120°F. or less. ZnO is believed to act by suppressing the formation of at. oxygen in the combustion products rather than by neutralizing SO<sub>3</sub>. Raising the temp. of the metal in air heaters prevented condensation of H<sub>2</sub>SO<sub>4</sub> on metal surfaces. This can be done by raising the temp. of entering air and of the flue gases. As a temporary measure, power stations may operate with flue gas temps. of 400°F. Reducing the Na concn. of residual fuel oil to less than 10 ppm prevents the corrosion and subsequent blocking of superheaters in boilers.—CA

**Treatment of Water for an Industrial High-Pressure Boiler Plant.** J. ARTHURS; J. ROBINS; & T. WHITEFOOT. *Trans. Inst. Chem. Engrs. (Gr.Br.)*, 37:72 ('59). High-pressure boiler plant at Wilton comprises 3 high-head boilers operating at 950 lb gage and a 4th radiant boiler operating at 1,700 lb gage. A 5th boiler will operate at 1700 lb. All of boilers are fired with pulverized coal; the 5th will be cyclone fired. Raw water is normally a purified blend of upland water with River Tees water, but may be untreated water from R. Tees. Water is of medium hardness and sometimes contains org. matter. Specified boiler water compn. for 950-lb boilers was (ppm): Tot. dissolved solids 700-1,000; NaOH 80-120, Na<sub>2</sub>SO<sub>4</sub> 100-140 (hydrazine was later substituted), Na<sub>2</sub>SO<sub>4</sub> at least 2.5 times the tot.

(Continued on page 58 P&R)

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(Continued from page 56 P&R)

alky. expressed as NaOH (this was later eliminated),  $\text{SiO}_2$  less than 40 (later cut to 25 to decrease turbine blade deposit formation), and suspended solids not to exceed 10% of the tot. dissolved solids. Feed treatment comprised the continuous addn. of  $\text{Na}_2\text{SO}_4$ , NaOH,  $\text{Na}_2\text{SO}_3$  and a small amt. of tannin discharge from pressure deaerators, with intermittent addn. of  $\text{Na}_2\text{HPO}_4$  soln. direct to boiler drum. Raw water was initially treated by a demineralization plant, consisting of 3 cation and 3 anion units. Cation and anion units are regenerated with  $\text{H}_2\text{SO}_4$  and soda ash soln., resp. All equip. from cation units to decarbonator is rubber-lined steel. NaOH is injected after decarbonator to raise the pH to 7.0 to 7.5. Each of 950-lb boilers is equipped with cyclone steam separators and spray separators in boiler drum. Purity of steam is monitored continuously. Avg. steam compn. is given. Solids content of satd. steam from these boilers is normally 0.4 ppm or less; silica content is now of the order of 0.05 ppm. During summer there was a fall in exchange capacity of cation resins, with a deterioration in water quality, owing to formation of a hard crust on upper layer of beds, consisting of a hard crust on upper layer of beds, consisting of alumina, inorg., and org. matter coalesced with fine exchange material, with some Fe bacteria. This was remedied by backwashing at higher rates and for longer times. On anion side, a gradual falling off of resin performance was attributed to deposition of org. matter. Backwashing failed to remedy this condition. Org. matter should be removed from water, especially when a strong-base anion exchange material is to be used. Later, an acid-base exchange plant was added to produce addnl. feedwater. This consisted of cation units and base-exchange units operating in parallel, followed by a blending of the 2 streams of water. This method is cheaper in first cost and operating cost, but produces a water having a solids content of 30-50% of that of raw water, and with higher hardness. For 1,700-lb boilers, all of feed is fresh makeup, apart from condensate from the feed heating cycle. A 2-stage deionization process with intermediate degassing was installed. Water was first clarified (coagulated with alum and acid, settled, and filtered), and then passed through cation units, a vacuum degasser, and

anion units. (Both vacuum and pressure deaeration were used to reduce dissolved O content of the feed water to 0.005 ppm.) NaOH and hydrazine solns. were added to deaerated water, and  $\text{Na}_2\text{HPO}_4$  soln. directly to boiler drum. Na flame photometers and modified Bran and Luebbe silkometers are used to monitor the quality of the water from both cation and anion units. Tot. dissolved solids content of boiler water was maintained at 70 ppm and  $\text{SiO}_2$  at 2 ppm, resulting in a  $\text{SiO}_2$  content in steam, of 0.03 ppm. Initially, repeated blowing down of boiler was required to reduce  $\text{SiO}_2$  content to this low level. While org. matter of water is reduced to about 1 ppm in clarification stage, recent examn. of strong-base anion exchange materials has shown considerable darkening, indicating that some org. fouling may be taking place. During overhaul, internal condition of boiler was found to be satisfactory.—CA

#### Demineralization of Boiler Feedwater and Organic Substances. C. JANSSEN. *Mitt. Ver. Grosskesselbesitzer*, No. 6, 172-8 ('59).

Org. substances, including humic acids are adsorbed both by coal-base acid exchangers and by strongly basic anion exchangers. This eventually results in a loss of capacity; this loss is relatively slow with the coal-base exchangers, but this type of exchange material must be avoided with certain waters. In the case of the strongly basic anion exchangers, part of the org. matter can be removed by washing with NaCl soln. in addn. to the usual regeneration step, but loss in capacity increases with the no. of cycles. The org. matter content of water is estd. by using  $\text{KMnO}_4$ , but the magnitude of the  $\text{KMnO}_4$  no. (mg/l) is no true measure of the difficulties encountered. With repeated use of the strongly basic anion exchanger, the pH of the demineralized water and the  $\text{SiO}_2$  content both increase. The Dutch firm Activit prepares a weakly basic exchange resin I.M.A.C. A-17 (hereafter referred to as A-17) which has the capacity of removing the larger part of the org. material. This material can be economically regenerated, with the removal of most of the org. material from the resin. Other means of removing org. matter were investigated, including decarbonation of the water with lime. The reduction as measured by the  $\text{KMnO}_4$  no.

(Continued on page 60 P&R)



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(Continued from page 58 P&amp;R)

was found to be slight except in the case of one water where the no. was reduced from 35 to 10. This treated water could be demineralized without significant loss in capacity of the anion resin. Chlorination can be used to reduce org. matter, but requires considerable Cl, appreciable time, and final dechlorination, so is little used. Flocculation with the addn. of Fe or Al chlorides or sulfates is successful in some cases, but not in others. An anion exchanger in chloride form, Asmit 259 (made by Activit), has a high capacity for removing org. matter. Most of the org. matter on the resin can be removed by regeneration with NaCl soln.; periodic washing with acidified BuOH removes the residual phenol etc. A satisfactory exchanger plant can be made up by using an initial tower contg. Asmit 259, followed by a tower contg. strongly acid resin IR 120: the water then passes through a decarbonator, and an A-17 filter, and finally through a mixed bed filter using Amberlite IR-120 and IRA-401. The Asmit 259 and A-17 remove the greater part of

the org. matter so that little reaches the mixed-bed filter. The Asmit 259 and A-17 resins are in platelet rather than granular form and require special precautions in regeneration. The resultant water has a min. salt content, low cond., and a higher pH than could be secured without the removal of org. matter.—CA

## HYDROLOGY, CONSERVATION, AND IRRIGATION

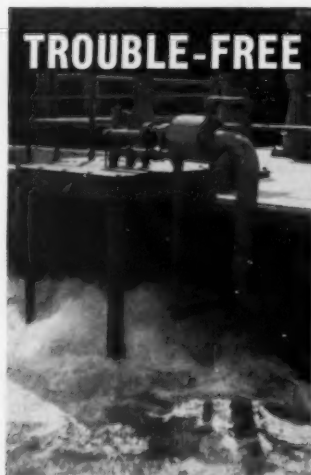
**Rainfall, Evaporation, and Land Use.** F. H. W. GREEN. *J. Inst. Water Engrs.* (London), 13:575 ('59). In studying factors affecting evapn., a knowledge of the potential evapn. of the area is essential. This is the evapn. which would occur, if the water supply is not limiting, on a grass sward free from significant obstructions. However, even in small areas, there can be wide departures from std. potential evapn. The effect of various land uses on potential evapn. is considered briefly.—WPA

(Continued on page 62 P&amp;R)

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(Continued from page 60 P&amp;R)

**Another Step Taken to Cut Water Evaporation.** *Chem. Eng.*, 67:No. 5, 58, 70 ('60). A new method has been developed in Australia for spreading cetyl alcohol on water to reduce evapn., using a special machine mounted on a boat. A coarse wire brush rotating at high speed shreds solid cetyl alcohol to a fine powder, which is then blown by a fan on to the water through a delivery tube. The costs of operation are small.—WPA

**Determination of Surface Runoff From Inclined Soil Surfaces.** J. DVORAK. *Deut. Gewässerkundl. Mitt.*, 3:74 ('59). Investigations are described into the amount of surface runoff from small areas of land during rainfall of different intensities and duration. A general relation was found between surface runoff, intensity and duration of rainfall, and inclination of the ground. This relation is expressed in an equation and diagrams. The investigations should be extended to surfaces of greater length.—WPA

**Evaporation Rate of Water From Open Surfaces Colored White.** M. R. BLOCK & T. WEISS. *Bul. Research Council, Israel*, 8A: 188 ('59). During Aug. '43, the water of the Dead Sea turned milky white due to calcium carbonate particles which had been dispersed through the surface brine. By Oct., it was found that the sea level was rather high, and the temperature of the water at a depth of 15 m was abnormally low. This was attributed to the whiteness reflecting the sun's rays, causing a lower temp. and a reduced rate of evapn. Expts. using small white polythene balls floating on water in white enamelled vessels have now proved this hypothesis. The white balls reflect the visible part of solar radiation, and only the infrared rays are absorbed and used for evapn. A similar expt. with black balls proved that the reduction of evapn. was due to the color of the balls and not to the fact that the surface area of the water was reduced. It is suggested that white balls of polythene or similar material might be used to reduce evapn. from open water reservoirs; they would have the advantages that they would respread over the surface of the water after disturbances and would be easily separated from the water when the water is required for use.—WPA

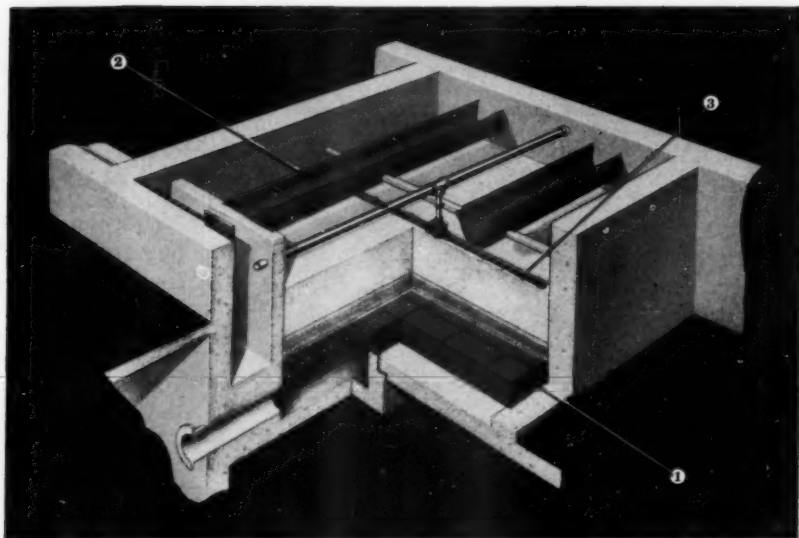
**pH Values of Rainfall, Snow Cover, and Ground Water in Vienna.** F. STEINHAUSER. *Arch. Meteorol., Geophys. u. Bioklimatol., Ser. B* (Vienna), 9:86 ('58). The distribution of frequency of pH values reported was detd. by means of a Beckman pH meter in 114 cases of rainfall either at 8 AM following the rain-day or immediately after the end of the pptn. Most values lay between 5 and 6, the range extending from 3.4 to 7.4. The yearly distribution of the pH values showed a max. in the spring and a min. in the winter. Daily measurements of the pH values of a snow-cover during periods with no pptn. are discussed. Comparisons of the mean values calcd. from the daily measurements with those detd. from the pptn. collected during a month showed that the latter were always considerably higher. Moreover, several series of measurements are reported which were made at short intervals during continuous rain; from these it was seen that pH values might vary considerably in the course of rainfalls of some duration. The influence of the wind direction prevailing during the rainfall is discussed. A 1-year series of measurements of pH of subsoil water yielded, apart from a few more or less short intervals of time, values above 7 in nearly every case, with but small variations in time.—CA

## CORROSION

**Problem of Cold, Warm, and Boiler Feed-water Treatment and Surface Protection.** O. JENTSCH. *Wasserwirtsch.-Wassertech.* (Ger.), 10:213 ('60). Corrosion in pipelines, boilers, and containers is prevented by feedwater treatment or by protection of metal surfaces. For that reason feedwater must be in lime-CO<sub>2</sub> equil., the carbonate hardness must be at least 2° (German hardness), and the O content at least 6 mg/l. O is removed from boiler water either with sodium sulfite or with hydrazine. Corrosion is reduced in hot water if O content and water hardness are as small as possible, and if there is no free CO<sub>2</sub> or other acids in water.—CA

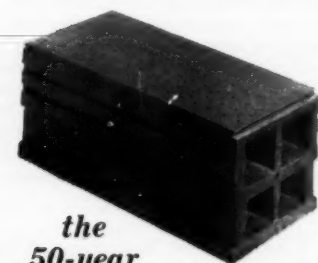
**Current and Potential Relations for the Cathodic Protection on Steel in Salt Water.** W. J. SCHWERTFEGER. *Corrosion*, 14: 446 ('58). The results are given of lab.

(Continued on page 64 P&amp;R)



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(Continued from page 62 P&amp;R)

studies on the cathodic protection of cold-rolled steel specimens exposed for 60 days to both stagnant and aerated city water to which was added 3% by weight of sodium chloride. Particular attention was paid to the significance of potential as a criterion for protection. Optimum protection was achieved when specimens were controlled at  $-0.77$  v with reference to the saturated calomel half-cell.—WPA

**Cathodic Protection of Water Treatment Plants.** F. O. WATERS. *Corrosion*, 16:487t ('60). The moving drives and chains in the chem. mixing and settling basins of rapid sand filtration plants can be given adequate cathodic protection; this is more economical and easier to maintain than adequate coatings. Cathodic protection is believed to be the most satisfactory method for protecting pressure filters, but better test methods and equipment are needed. Overprotection can cause very rapid calcification and cementing of the filter gravel, so that pneumatic chisels are needed for repairs.—CA

**Film Formation Versus Film Maintenance in Cooling Water Inhibitor Performance.** P. R. PUCKORIUS & W. J. RYZNER. *Corrosion*, 16:473t ('60). Corrosion inhibitors in open recirculating cooling water systems require rapid and complete film formation for max. effectiveness. The protective film is established on clean surfaces by initial treatment with inhibitor at high dosage levels. Protection then can be maintained by continuous treatment at substantially lower levels. If operational difficulties cause loss of the protective film, low-level treatment may then result in severely increased corrosion and deposition. Lab. corrosion, deposition, and consumption studies with polyphosphate-based and Cr-based inhibitors illustrate the advantages of high level start-up and low level maintenance treatments. These data are confirmed by field experience.—CA

**Corrosion by Urban Cooling Waters.** S. SUSSMAN. *Corrosion*, 16:471t ('60). Untreated circulating cooling waters are likely to become corrosive when low-alky. waters are present in an area with a relatively high atm.  $\text{CO}_2$  content. Untreated circulating waters are compared with makeup waters for 8 eastern cities for such factors as pH,

alky., Cl content, sulfate/chloride ratio, and corrosion products. New York City water is discussed specifically. Corrosion can be mitigated by alk. pH adjustment with maintenance of satisfactory chromate concns.—CA

**Simultaneous Action of Organic Inhibitors and Cathodic Polarization on the Corrosion of Iron.** L. I. ANTROPOV. *J. Sci. & Ind. Res.*, 18B:314 ('59). Calculation of increase in cathodic protection of metals, particularly iron, by alteration of anodic and cathodic polarization. Data show a decrease in corrosion rate when electric current is applied to organic inhibitors in solutions.—Corr.

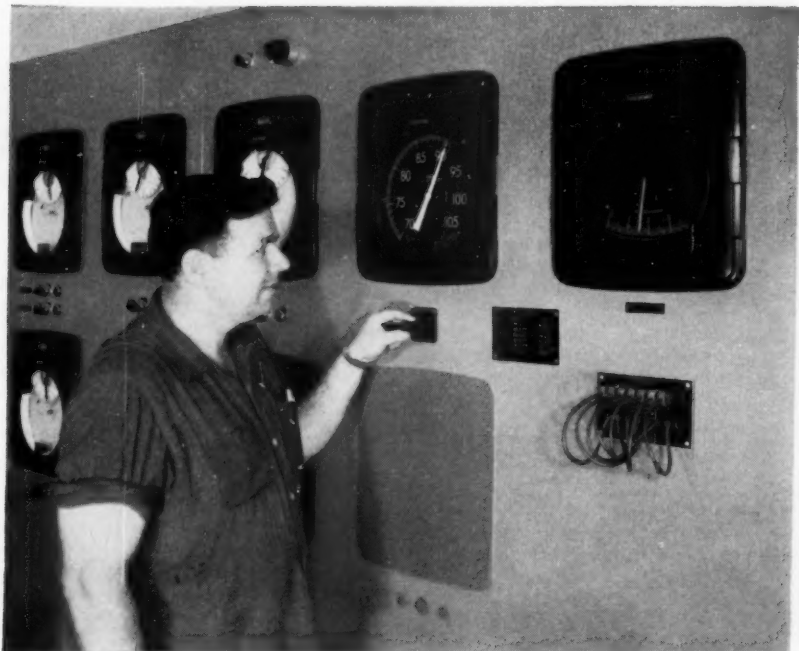
**Results of Marine Corrosion Tests on 4% Chromium Steels.** E. HERZOG. *Corrosion et Anticorrosion* (Fr.), 7:312 ('59). Weight loss and depth of corrosion of specimens contg. slight additions of nickel or aluminum. Conditions included exposure to marine atmosphere, immersion in sea water, various types of surface preparation and heat treatment and asphalt painting of surfaces. 6 references.—Corr.

**Kinetic Studies on the Iron-Steam Reaction.** B. BRIGOLI ET AL. *Energia Nucleare* (Milan), 6:330 ('59). Iron containing porous material was prepared to determine its chemical and mechanical behavior during the steam-iron hydrogen-producing reaction. Materials contg. about 50–90% iron in aluminum oxide were prepared, and their mechanical behavior tested. The 90% iron product was used for kinetic studies on the oxidation and reduction reaction rates. Results are reported and exptl. equipment is described.—Corr.

**Anodic Dissolution of Magnesium Alloys in Aqueous Salt Solutions.** R. GLICKSMAN. *J. Electrochem. Soc.*, 106:2:83 ('59). The anodic dissolution of a magnesium AZ10A alloys has been studied by measuring corrosion rates and electrode potentials as functions of current density, pH and electrolyte concn. Results are interpreted in terms of a rate-controlling proton transfer step through a surface film of magnesium oxide and/or hydroxide. The effect of different alloy compositions and soluble metal

(Continued on page 66 P&amp;R)





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(Continued from page 64 P&amp;R)

additives to the electrolyte on the anodic corrosion rate and electrode potential also has been measured.—*Corr.*

**Synthetic Rubbers for Corrosion Protection.** ST. REINER. *Werkstoffe u. Korrosion* (Ger.), 9:1 ('58). The properties and applications of the synthetic rubbers are reviewed. Methods for the bonding of vulcanized high polymers to metals are listed, including the brass process in which a layer of 70:30 brass is first electro-deposited on the metal. A table gives the bond strengths at 20 and 120°C for different combinations of bonding methods and synthetic rubbers.—*Corr.*

### SALINE-WATER CONVERSION

**Silver Desalts Water.** *Mfg. Chem.*, 31:50 ('60). A process has been developed for the demineralization of water with silver. A slurry of silver sulfate is used to ppt. chlorides, and the silver chloride is treated with

sulfur trioxide to regenerate the silver sulfate for reuse. The filtrate is treated with lime to ppt. magnesia, which is separated and roasted in a furnace. A further supply of lime is added with carbon dioxide under pressure, pptg. gypsum and leaving sodium bicarbonate in solution. The gypsum is heated at 1,200–1,400°C, regenerating lime, and the sulfur trioxide and steam are used to convert the silver chloride to sulfate. The bicarbonate solution is saturated with bicarbonate ions by adding the previously extracted magnesia and carbon dioxide at 10–12 atm., pptg. sodium bicarbonate. The filtrate contg. magnesium bicarbonate is treated with a further supply of magnesia, forming magnesium carbonate, which is separated from hot solution and heated at 800–1,000°C to regenerate magnesia and carbon dioxide, which are both reused in the process.—*WPA*

**Solar Stills in Iraq.** A. V. BRANCKER. *Nature* (London), 185:362 ('60). Expts. with solar stills and related units have been carried out at the College of Science, Bagh-

(Continued on page 68 P&amp;R)

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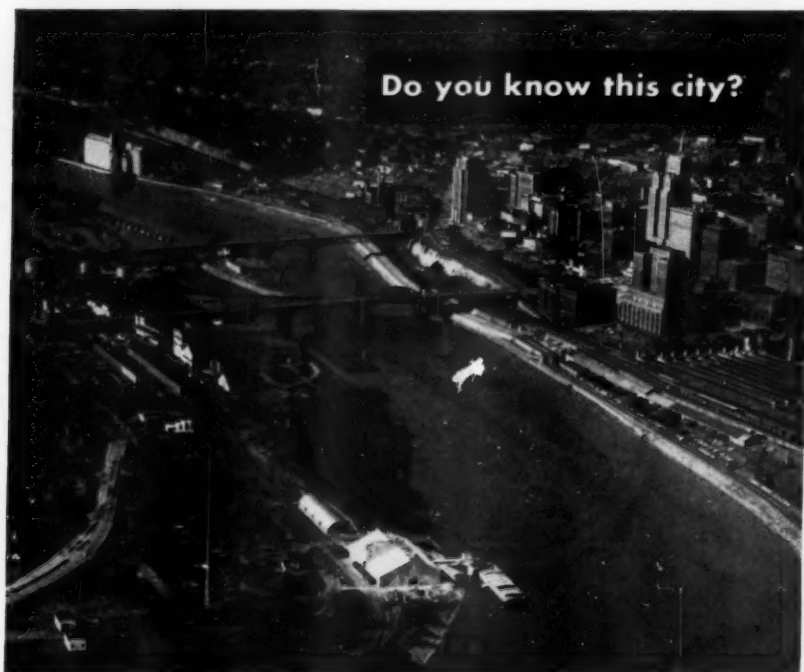
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(Continued from page 66 P&R)

dad, in an attempt to provide fresh water for Bedouin communities, and to investigate the concn. of natural to heavy water. Several designs of solar still for each of the applications were tested, and the results obtained are outlined. Basic equations for the solar evaporation process are given.—WPA

#### Saline Water Conversion Report for 1957.

US DEPT. OF THE INTERIOR, Washington, D.C. ('58). In addition to the usual report on the activities of the US Office of Saline Water during the year, this annual report on the demineralization of saline waters contains a brief description of the more important research and development work carried out since the initiation of the Office in 1952; a list is appended of the relevant studies known to be in progress, including both those sponsored by the US Dept. of the Interior and those sponsored by other bodies. The laboratory and economic studies have now narrowed the field to be considered from about 20 phenomena or processes to 5 broad groups, each of which is considered individually—namely, distillation processes using artificial heat; solar distillation processes; processes utilizing membranes; freezing processes; and other processes (including solvent extraction, and the use of nuclear energy or high-frequency electric currents).—WPA

**One Dollar per 1,000 Gallons.** F. A. LOEBEL. *Am. City*, 74:178 ('59). The author discusses the economics of demineralizing sea water, giving details of costs for two hypothetical multistage flash distillation plants. A pilot plant is to be constructed at the Southern California Edison's Mandalay steam plant for further research on this subject in an effort to reduce the required heat-transfer surface and the pumping power. The various types of evapn. process employed are reviewed, and the possibility of reducing costs of the process is discussed.—WPA

**Continuous Water Distillation Working on the Heat-Pump Principle.** *Tech. Gids* (Netherlands), 26:781 ('57). A new range of app. has been developed in the Netherlands for demineralization of water by thermo-compression distn. An illustrated description is given of the app., which can be

obtained with capacities of 3.5–500 liters/hr. A special model is available for treatment of very saline or hard waters, the conc. being discharged continuously to prevent formation of salt.—WPA

#### Demineralization of Water by Freezing.

L. KERVAN. *Eau* (Paris), 44:243 ('57). Further information is given on Trépaud's method for the demineralization of water by freezing in large and small plants. Analyses were carried out on sea water before and after freezing, and on the ice formed during demineralization, to det. the concns. of salts present, and variations in their absolute and relative values. Results are presented in graphs. The concns. of salts of the alkali and alkaline earth metals, sodium, potassium, calcium, and magnesium are considered and compared. The concns. of the trace elements silicon, aluminium, copper, zinc, manganese, and iron are discussed briefly. The concns. of the former in the demineralized sea water vary according to their solubility, whereas the latter were not removed by freezing.—WPA

**Electrodialytic Membranes.** *Bul. mens. inform. Assn. franc. Et. Eaux*, No. 63, II.1–II.8 ('58). The costs and economics of using electrodialysis for the demineralization of brackish water are discussed, and the basic principles of the method reviewed. Operational details for a typical plant are outlined, and a description of the plant installed at Tobruk, Libya, is given.—WPA

### LABORATORY METHODS

**Determination of Dissolved Oxygen in Polluted Waters.** T. OKURA; K. GOTO; & T. FURUKAWA. *Mem. Fac. Eng. Hokkaido Univ.*, 11:11 ('60). The Winkler, Miller, and polarographic methods for detn. of DO and BOD in polluted H<sub>2</sub>O were compared. Highly polluted H<sub>2</sub>O contained a high concn. of DO detd. polarographically, while the other methods detected only a small concn. Org. matter, NO<sub>3</sub>, and Fe salts interfere with Winkler and Miller detn. DO of 8.05, 0.0, and 1.10 mg/l were detd. in Kokusaku paper-mill waste by polarographic, Winkler, and Miller methods. Potato-starch effluent at a 20:1 dilm. had a DO content of 7.75, 6.62, and 5.99 mg/l, and at a 100:1 dilm., had

(Continued on page 70 P&R)

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(Continued from page 68 P&amp;R)

a DO content of 8.96, 8.42, and 8.28 mg/l as detd. by polarographic, Winkler, and Miller methods.—CA

**Simple Arrangement for the Polarographic Determination of Dissolved Oxygen in Industrial Wastes.** D. KLIMA. *Voda*, 36: 148 ('57). The app. comprised a sensitive galvanometer, a Kohlrausch drum, and a dropping Hg electrode. In contrast with other commonly used methods, nitrites do not interfere in this detn. The max. of the polarographic wave should be measured at -1.6 v.—CA

**Spectrophotometric Determination of Dissolved Oxygen in Water.** B. D. LA MONT & N. E. GORDON JR. *US At. Energy Com., WCAP-917* ('58). Improved sampling and anal. techniques for the Winkler method are proposed. Hypodermic syringes are used to add the reagents to the sampling vessel to prevent atm. contamination. The liberated I is extd. with  $\text{CHCl}_3$ , and the extinction of the soln. is measured and compared with a standard curve. Dissolved O in  $\text{H}_2\text{O}$  can be detd. in the concn. range of ppm or parts per  $10^6$ .—CA

**Determination of Barium as Rhodizonate in Mineral Waters.** K. SUCHÝ. *Fysiat. Vestník*, 35:157 ('57). The sample to be analyzed is evapd. to 40-50 ml, a satd. soln. of Na rhodizonate is added dropwise, and the mixt. is heated to  $50^\circ\text{C}$ . The ppt. is filtered off, washed with  $\text{H}_2\text{O}$  and alc., and dried at  $130^\circ\text{C}$ . Na, K, Li,  $\text{NH}_4$ , Mg, and Ca do not interfere. Sr must be removed beforehand.—CA

**Colorimetric Microdetermination of Copper in Water—A Survey of Available Methods.** B. TUCK & E. M. OSBORN. *Analyst* (Gr.Br.), 85:105 ('60). An evaluation of the available colorimetric methods (Na diethyldithiocarbamate, bis-cyclohexanone oxalyldihydrazone, oxalyldihydrozide, neocuproine, and 2,2'-biquinoline (I) for the direct microdetn. of Cu is reported. The presence of interfering substances, such as Fe, Ni, Zn, and of hydrazine and volatile amines, such as cyclohexylamine and morpholine, was investigated. The method employing I is recommended; it is rapid, accurate, and unaffected by the above mentioned interferences.—CA

**Spectrographic Determination of Trace Elements in Natural Waters—Concentrating Ni, Co, Ag, Cu, V, Sn, Bi, Fe, Pb, and Mn by Means of Sodium Diethyldithiocarbamate.** I. T. KLIMOV & V. Y. EREMENKO. *Gidrokhim. Materialy* (USSR), 29:254 ('59). The extn. was checked under different pH values, and the no. of the extns. necessary to obtain the set % of the extd. material was calcd. The results of the extn. at pH 6 for  $\text{Co}^{II}$ ,  $\text{Mo}^{VI}$ , VV,  $\text{Sn}^{IV}$  were too low, therefore the extn. above pH 6 was not explored. At pH 5 over 50% of  $\text{Cu}^{II}$ ,  $\text{Ag}^I$ ,  $\text{Co}^{II}$ ,  $\text{Ni}^{II}$ , VV,  $\text{Sn}^{IV}$ ,  $\text{Mn}^{II}$ ,  $\text{Pb}^{II}$ ,  $\text{Bi}^{III}$  were extd. The quant. extn. of the above mentioned elements with  $\text{CHCl}_3$  by the use of carbamate occurs at pH 4.7-4.9, repeating the extn. 3-4 times. The method of spectrographic detn. is the same as described previously.—CA

**Total-Hardness Determination in Water by Titrating With Potassium Stearate, With Eriochrome Black T as Indicator.** D. CEAUSESCU. *Acad. rep. populare Romine, Baza cercetari Stiint. Timisoara, studii cercetari stiint. chim.* (Rum.), 6:127 ('59). Neutralize 100 cc  $\text{H}_2\text{O}$  with 0.01N HCl (methyl orange), with 0.3-0.5 cc excess (for bicarbonate decompn.), boil 2-3 min, cool to  $40-50^\circ$ , add 2 cc  $\text{NH}_4\text{Cl}-\text{NH}_3$  soln. (56 g  $\text{NH}_4\text{Cl}$ , 350 cc 25%  $\text{NH}_3$ , and  $\text{H}_2\text{O}$  up to 1 l) with 0.1 g Eriochrome Black T + NaCl (1:100). The soln. turns wine-red. Titrate with 0.1N K stearate to blue color, and add 0.5-1 cc excess; titrate with 0.1N  $\text{MgCl}_2$  to rose-violet. Prep. the reagent by dissolving 28.6 g stearic acid in EtOH 330, BuOH 330, and  $\text{H}_2\text{O}$  330 cc on a heated water bath. Titrate a small hot sample, with 10% KOH soln., with phenolphthalein, to light rose, and add the appropriate amt. of KOH to the bulk of the soln. without any indicator. If turbidity appears upon cooling, filter. The factor of K stearate is detd. with a mixt. of 2.50 cc 0.1N  $\text{MgCl}_2$  and 2.50 cc 0.1N  $\text{CaCl}_2$ . The amt. of K stearate consumed by re-titrating with  $\text{MgCl}_2$  is deducted. The disturbing effects of  $\text{Mn}^{++}$ ,  $\text{Fe}^{++}$ ,  $\text{Al}^{+++}$ , and  $\text{Cu}^{++}$  are eliminated by pptn. with  $\text{Na}_2\text{S}$  or by masking with KCN.—CA

**Evaluations of Various Methods and Reagents for Total Hardness and Calcium Hardness in Water.** C. A. GOETZ & R. C. SMITH. *Iowa State J. Sci.*, 34:81 ('59).

(Continued on page 72 P&amp;R)





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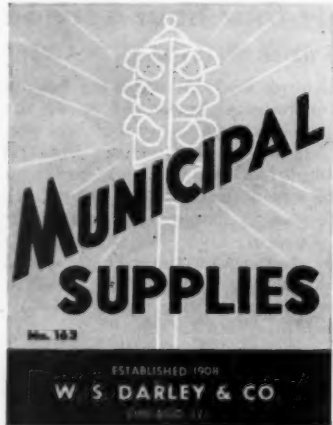
Gravimetric analysis for tot. hardness in  $H_2O$  is slow but accurate; titration with soap is rapid but inaccurate, esp. if much Mg is present. The major part of the paper is devoted to evaluation of newer reagents, buffers, pH adjustments, and methods for tot. hardness and Ca hardness. Results are reported in 14 tables and 13 figures, each contg. several curves.—CA

**Simple Field Method for Determination of Calcium and Magnesium in Water.** H. GUNDLACH; W. KOCH; & G. STOVESAND. *Z. Erzbergbau u. Metallhüttenw.* (Ger.), 13: 179 ('60). Total hardness is 1st detd. by a modification of the "complexometric" titration with di-Na EDTA. In place of a soln. the titration agent is used in tablet form (Durognost tablets), the tablet contg., in addn. to EDTA, the indicator and buffer. Ca is detd. separately by addn. to the  $H_2O$  sample of a few drops of 3N NaOH and murexide indicator, followed by addn. of Durognost tablets until the color changes from red to violet.—CA

**Determination of Calcium and Magnesium in Waters by Automatic Titration.** J. HASLAM; D. C. SQUIRRELL; & I. G. BLACKWELL. *Analyst* (Gr.Br.), 85:27 ('60). A method has been developed for the direct detn. of calcium and magnesium in the same sample of water by potentiometric titration with standard EDTA soln. The sample is acidified, boiled to remove carbon dioxide, and cooled. An appropriate vol. of sodium hydroxide soln. is then added, together with a known vol. of a std. mercuric soln. The calcium is then titrated with a std. soln. of EDTA in an automatic recording titrimer, using a bridged calomel reference electrode and a mercury-plated silver indicator electrode. The soln. is then acidified, and is made appropriately alkaline with ammonia soln., and the titration with EDTA is continued to give the tot. concn. of calcium and magnesium present.—WPA

**Determination of Fluorine in Potable Waters.** C. SEELKOPF & J. ROMERO. *Rev. Fac. Farm., Univ. Andes* (Venezuela), 1:27 ('58—

(Continued on page 74 P&amp;R)



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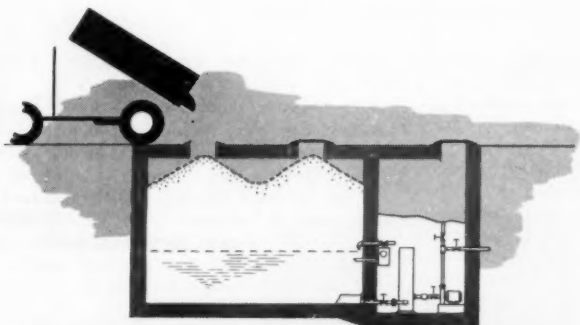
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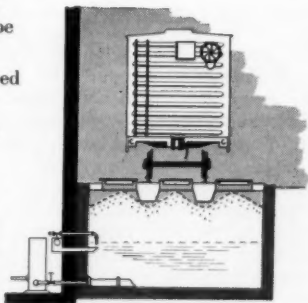


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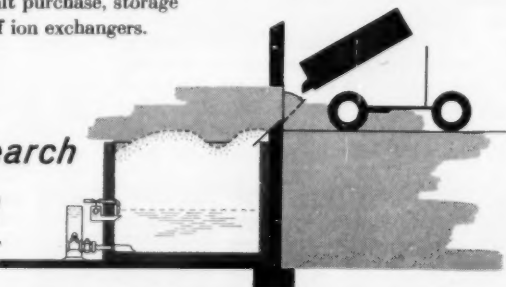
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59). In detg. F, it is necessary to sep. it from other ions impeding its detection by steam distn. of the concd. soln. in the presence of perchloric acid. Colorimetry with Na alizarin sulfonate-ZrOCl<sub>2</sub> lake gave the best results. The potable H<sub>2</sub>O of several cities of Mérida State contained in all cases <1 mg/l, considered the prophylactic concn. for preventing dental caries, mostly running 0.3-0.4 mg/l, which, however, is higher than the common F content of European alpine waters. Artificial F addn. to the water supply of an Andean village is advocated as an exptl. measure.—CA

**Determination of Sulfate Ion in Natural Waters by Amperometric Titration.** M. A. LIPOVSKII. *Trudy, Vsesoyuz. Nauch.-Issledovatel. Geologo-razvedoch. Neft. Inst. (USSR)*, 11:273 ('58). The method of amperometric titration with a Hg dropping cathode is applied for the detn. of SO<sub>4</sub><sup>2-</sup> in natural H<sub>2</sub>O. A polarograph and a mirror galvanometer with a shunt are used. The voltage is 0.8 v (satd. Hg electrode). The technique is: mix H<sub>2</sub>O sample 25, 0.1N KNO<sub>3</sub> soln. 25, and MeOH 25 ml in a 100-ml beaker, and titrate with a 0.1N Pb(NO<sub>3</sub>)<sub>2</sub> soln.; gravimetrically det. the titer. Since MeOH reacts, det. a MeOH blank and subtract. Quant. ppt. the HCO<sub>3</sub><sup>-</sup> with SO<sub>4</sub><sup>2-</sup>, det. it acidimetrically, and, with the aid of a corresponding calibration curve (ml, Pb(NO<sub>3</sub>)<sub>2</sub>:mg HCO<sub>3</sub><sup>-</sup> in 25 ml soln.), subtract from the total equiv. vol. Remove H<sub>2</sub>S, if present, by boiling. The accuracy of the method, compared with gravimetric results, is up to 0.244 meq/l.—CA

**Rapid Volumetric Method for the Determination of Sulfate in Water.** J. R. KERR. *Proc. Soc. Water Treatment Exam. (Gr. Br.)*, 8:175 ('59). The detn. of SO<sub>4</sub><sup>2-</sup> by the Little method is modified to eliminate the interference of Ca. To an aliquot of water contg. less than 15 mg SO<sub>4</sub><sup>2-</sup>, add several drops of *p*-nitrophenol indicator and sufficient 0.1N HCl to recolorize the soln. Add 5 ml 0.1N HCl, evap. to a vol. of 5-10 ml, cool, and add 15 ml 0.02N BaCl<sub>2</sub>, followed by 25 ml Me<sub>2</sub>CO. Add 4 drops of sodium rhodizonate soln. Slowly back-titrate with 0.02N K<sub>2</sub>SO<sub>4</sub>. Repeat the procedure on 100 ml of distd. water. When present in concns. of not more than 50 ppm, the fol-

lowing ions cause no interference: silicate, F<sup>-</sup>, Cu<sup>2+</sup>, Zn<sup>2+</sup>, Fe<sup>3+</sup>, PO<sub>4</sub><sup>3-</sup>, PO<sub>4</sub><sup>2-</sup>. Fe<sup>3+</sup> does not interfere at a concn. of 5 ppm; interference due to higher concns. may be overcome by adding several drops of 1% NH<sub>4</sub>OH·HCl soln. Standard solns. of 10, 25, 40, 60, and 100 ppm SO<sub>4</sub><sup>2-</sup>, analyzed by this method indicated 9, 28, 40, 62, and 97 ppm SO<sub>4</sub><sup>2-</sup>, resp. Comparable results were shown on natural and artificial waters of varying hardness and alkyl.—CA

**Trilonometric Determination of Small Amounts of Sulfates in Water.** G. N. NECHIPORENKO & M. I. KRIVENTSOV. *Gidrokhim. Materialy (USSR)*, 29:211 ('59). A quantity of water, contg. approx. 1 mg sulfate ion, is acidified in porcelain evapg. dish with 5% HOAc (for carbonate and bicarbonate decompn.), and evapd. to dryness. The residue is dissolved in 0.25% HOAc and placed in a centrifuge tube. Pb(NO<sub>3</sub>)<sub>2</sub> (1%) soln. is next added, and soln. made 50% with EtOH. After 4 hr, the ppt. of PbSO<sub>4</sub> is centrifuged and washed with 50% EtOH until no Pb can be detected. After soln. of the ppt. in 10% NH<sub>4</sub>OAc and addn. of NH<sub>4</sub>OH-NH<sub>4</sub>Cl buffer (pH 8-10), Pb is titrated with 0.01N soln. of Trilon B with Eriochrome Black T as indicator. The error of detn. is ±2.7%. Ca ions do not interfere. The results may be too high, owing to formation of PbSO<sub>4</sub>·PbCl<sub>2</sub> in the ppt., when the content of chlorides in water is large.—CA

**Measurement of Silicic Acid Concentration in Vapor and in Drinkable Water.** B. I. PESKOVOL. *Teplotnergetika (USSR)*, 7:2:87 ('60). The elec. scheme is drawn for automatic distribution, mixing, reagent addns., and ultimate detn. by a photometer of the Si concn. of a set of samples; the colorimetric analysis is based on the yellow color of the complex [Si(Mo<sub>2</sub>O<sub>7</sub>)<sub>2</sub>]<sup>4-</sup>. Max. holdup time for each sample is 5 min., the time needed for the complex formation. SiO<sub>4</sub><sup>2-</sup> concn. can be detd. with an error of 0.001 mg/l; the analyzer was used in some industrial plants within the ranges 0-0.1; 0-1; 0-10 mg/l SiO<sub>4</sub><sup>2-</sup> by varying the sensibility of the photosensitive resistances on which the light is focused after being filtered through the soln. to be tested.—CA

(Continued on page 76 P&amp;R)

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(Continued from page 74 P&amp;R)

**Determination of Chromate Ion With a Detector Tube.** Y. KOBAYASHI. *Japan Analyst*, 7:560 ('58). A method for the rapid detn. of chromate (more than 2 ppm) in water using a detector tube is outlined. The tube contains silica gel impregnated with lead acetate; the length of the colored layer formed is independent of pH value within the range 2.0-8.0 and of temp. within the range 15-60°C. The error is less than 10%.—WPA

**Determination of Naphthenic Acid in Natural Waters Containing Humic Acid.** E. A. BARS & A. N. FIKHMAN. *Novost. Neft. Tekhn. Geol.*, 7:36 ('58). A method for the detn. of naphthenic acid in natural waters contg. humic acid is described. The method is based on the difference in behavior of the 2 acids when treated with acidified water, and benzene or chloroform. Humic acid is completely recovered from the water as a brown layer on top of the soln. and is estd. colorimetrically. Naphthenic acid dissolves in benzene or chloroform, and is detd. turbidimetrically. Detailed procedure is given. Tests on synthetic mixts. showed that naphthenic acid can be completely recovered.—WPA

**A Tetraphenylborate Method for the Determination of Potassium in Natural Waters.** A. A. REZNIKOV & A. A. NECHAEVA. *Inform. Sbornik, Vsesoyuz. Nauch.-Issledovatel. Geol. Inst.*, No. 4, 145 ('56). Directions are given for the detn. of K in natural waters with  $\text{Na}[\text{B}(\text{C}_6\text{H}_5)_4]$  (I). In the gravimetric method, make the K soln. 0.1N acidic by adding 1 ml HCl (1:1) for 50-ml soln., add an excess of aq. soln. of 3% I, and stir. Allow the ppt. to settle 10-15 min, and filter through a glass filter No. 2, wash with wash-liquid (II) (a satd. soln. of  $\text{K}[\text{B}(\text{C}_6\text{H}_5)_4]$ ), and dry at 120-30°C; the factor  $K = 0.1091$ . In the volumetric method, ppt. K as in the gravimetric method with 0.035N I soln., filter through a paper filter, and wash with 5-10 ml II. Add to the filtrate 10-20 ml 0.035N  $\text{NH}_4\text{Cl}$  soln., filter the  $\text{NH}_4[\text{B}(\text{C}_6\text{H}_5)_4]$  ppt, and wash with II. Titrate the filtrate with 0.05N NaOH.—CA

**The Formaldehyde Method for Determining Ammonia.** D. STOCKDALE. *Analyst* (Gr.Br.), 84:667 ('59). The formaldehyde

method for the detn. of ammonia, in which excess formaldehyde is added to the soln. of the ammonium salt and the liberated acid is titrated after a few min against std. sodium hydroxide soln. with phenolphthalein as indicator, is subject to small sources of error. The author describes a modification of the method which is more accurate for detg. ammonia in an ammonium salt soln.—WPA

**Oxidized Nitrogen in Waters and Sewage Effluents Observed by Ultraviolet Spectrophotometry.** R. C. HOATHER & R. F. RACKHAM. *Analyst* (Gr.Br.), 84:548 ('59). Expts. have shown that nitrate can be detd. rapidly by measurement of the ultraviolet absorption at 2100Å. The sensitivity and accuracy of this method compare favorably with the usual chem. methods for most waters of good organic quality, and the results are in agreement with such methods. However, in some high-quality well waters, river waters, and sewage effluents, it appears that the content of oxidized nitrogen is not always completely assessed by the usual detns. of nitrite and nitrate, and for such samples ultraviolet absorption indicates the presence of a substantial proportion of the oxidized nitrogen in a form that only appears gradually as nitrate when the sample is kept for a few weeks.—WPA

**Colorimetric Determinations of Nitrite and Nitrate Nitrogen in Brackish Coastal Waters.** J. B. PRICE & R. R. PRIDDY. *Bul. Marine Sci. Gulf & Caribbean*, 9:310 ('59). A simple, rapid colorimetric procedure has been developed for detg. the nitrate and nitrite content of brackish waters. The colorimetric reaction is based on diazotization of sulfanilic acid by  $\text{NO}^+$  and subsequent coupling with 1-naphthylamine.  $\text{NO}_3^-$  is reduced to  $\text{NO}^+$  with powd. Zn. Reagents are mixed in a single powder with  $\text{MnSO}_4$  and citric acid to complex Fe and Al. Powder is added after the pH of the brackish water has been reduced to 2 with AcOH. The procedure can be used to det. 0.03-0.2 ppm  $\text{NO}_3^-$ .—CA

**Rapid Method for the Determination of Nitrate in Drinking Water Using 3,3'-Dimethylnaphthidine.** E. W. HAMMOND. *Proc. Soc. Water Treatment Exam.*, 8:173

(Continued on page 78 P&amp;R)





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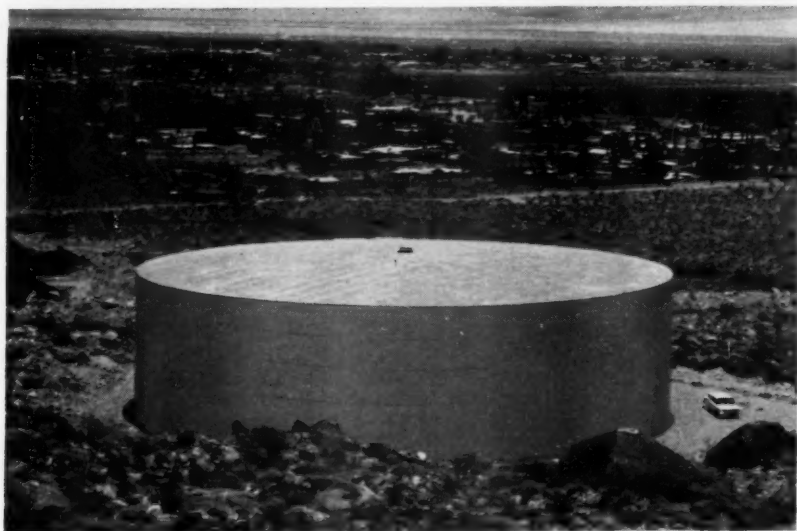
('59). A sample of 2 ml is treated with 4 ml 0.025% 3,3'-dimethylnaphthidine reagent. Within 20-30 min the soln. is dild. to 50 ml with 50%  $H_2SO_4$ . The absorption is det. on a photoelec. absorptiometer and follows Beer's law in the range 1-7 ppm  $NO_3^-$ . A visual procedure is described. Interference by chlorine concns. exceeding 1 ppm may be eliminated by adding 1 drop 2%  $NaAsO_2$  soln. Cl interference is negligible below 200 ppm. Nitrite in concentrations less than 1 ppm causes no interference. Org. matter and other ions commonly found in drinking water do not interfere. Oxides of Fe and Mn cause a slight interference. Comparison of the redn. method of detg.  $NO_3^-$  with this method show close agreement on drinking waters, river waters, sewage effluent, and raw sewage liquors of varying  $NO_3^-$  concns. —CA

**Determination of Nitrates in Water.** L. PROCHAZKOVA. *Z. Anal. Chem.*, 167:254 ('59). A method for detg. the concn. of nitrates in water relies on the reduction of nitrate ions to nitrite ions by treatment with hydrazine in normal caustic soda soln. in the presence of a copper catalyst. The reaction takes 30 min for completion. Any nitrite ions present initially are unaffected by the hydrazine, thus permitting the detn. of nitrate and nitrite ions in the presence of one another. The excess hydrazine is removed with acetone, and sulphanilic acid and  $\alpha$ -naphthylamine are added to form a complex with the nitrite ions. For detg. the concn. of nitrates between 0.01 and 0.4 mg/l the accuracy of the method is within 2%. —WPA

**A Rapid Routine Method for the Microdetermination of Dissolved Oxygen in Water.** J. BARGH. *Chem. & Ind. (London)*, p. 1307 ('59). A rapid routine method or the microdetn. of dissolved oxygen in water is described, and illustrated with the aid of diagrams. The main feature of the method is the sampling vessel used, the advantages of which are listed, and the provision for the immediate processing of the contents as soon as the sample is taken. Details of the apparatus and procedure, are given. The Winkler method, which has been shown to be accurate to less than 0.001 mg/l, is used, but titration with sodium thiosulfate soln. is used in preference to extraction and color comparison; the end-

(Continued on page 80 P&R)

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(Continued from page 78 P&R)

point is detd. amperometrically. Corrections are made for most of the interfering substances, and for the oxygen added with the processing reagents. The method is suitable for detg. oxygen in the presence of oxidizing or reducing agents, with the exception of ferrous iron, which must be removed by ion exchange if present in significant amts. The method can be used satisfactorily to det. dissolved oxygen in boiler feedwater, in boilers for the production of steam, and in deaeration plants.—WPA

**Spectrophotometric Determination of Monomeric Silica and of Its Low Molecular Weight Polymers in Natural Waters.**

—**Observations on the Silicomolybdc Complex Method.** B. VISINTIN & S. MONTERIOLO. *R.C. Ist. sup. Sanit.* (Rome), 22: 773 ('59). As part of an exptl. study on the state of silica in natural waters, the authors examined the exptl. variables affecting the detn. of monomeric silica by the ammonium molybdate method when the color of the yellow silicomolybdc complex is measured spectrophotometrically and the interference of phosphate is overcome by the addition of oxalic acid. It was concluded that the photometric readings were dependent on the temp. (variations corresponding to less than 0.5 mg/l silica for each deg. Centigrade), and that if the period between the addition of oxalic acid and the photometric readings reached 5 min the oxalic acid not only destroyed the phosphomolybdc acid but also decolorized the silicomolybdc complex. In the method adopted, 3 min was allowed for the formation of the yellow complex and the photometric readings were made 2 min after the addition of oxalic acid. The method was used to examine water from Fabio's spring in Lacco Ameno after "ag-

ing" for various periods, and the results show that the dissolved silica is entirely monomeric.—WPA

**A Semimicro Rapid Determination of Oxygen Dissolved in Water.** YUN-FENG JEN & ME-KENG HSU. *Hua Hsueh Shih Chieh*, 14:41 ('59). This is a modified Harpers process adapted to field anal. work. The equipment is portable, and the procedure is simple. This method is sufficiently accurate and may be also applied for the detn. of free  $\text{CO}_2$  in  $\text{H}_2\text{O}$ .—CA

**OTHER ARTICLES NOTED**

*Recent articles of interest appearing in periodicals of the water supply field are listed below.*

"How Industry Promotes Water Conservation." L. T. DAVIES. *Public Wks.*, 91:9:124 (1960).

"Continuous Measurement of Oxygen to Control and Regulate Aeration." GEHARD STRAKE. *Wtr. & Sew. Wks.*, 107:388 (1960).

"Water and Sewerage Training School." GLENN HANDS. *Am. City*, 7:9:97 (1960).

"No More Algae Problems." H. S. THORGRIMSEN. *Am. City*, 75:10:185 (1960).

"Steps in Solving Our Problems of Pollution Control." *Public Wks.*, 91:10:97 (1960).

"Industry and Water Resources." M. D. GRISWOLD. *J. WPCF*, 32:509 (1960).

"Partial Defluoridation of Water." F. J. MAIER. *Public Wks.*, 91:11:90 (1960).

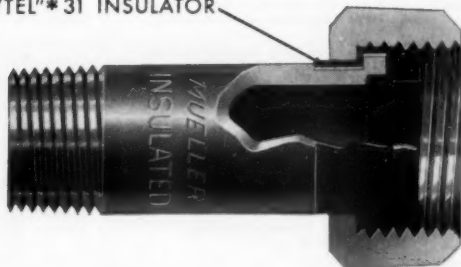
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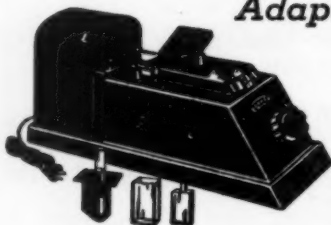
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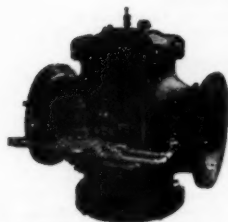
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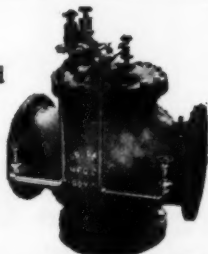


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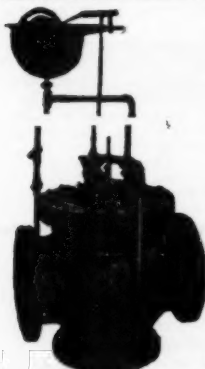
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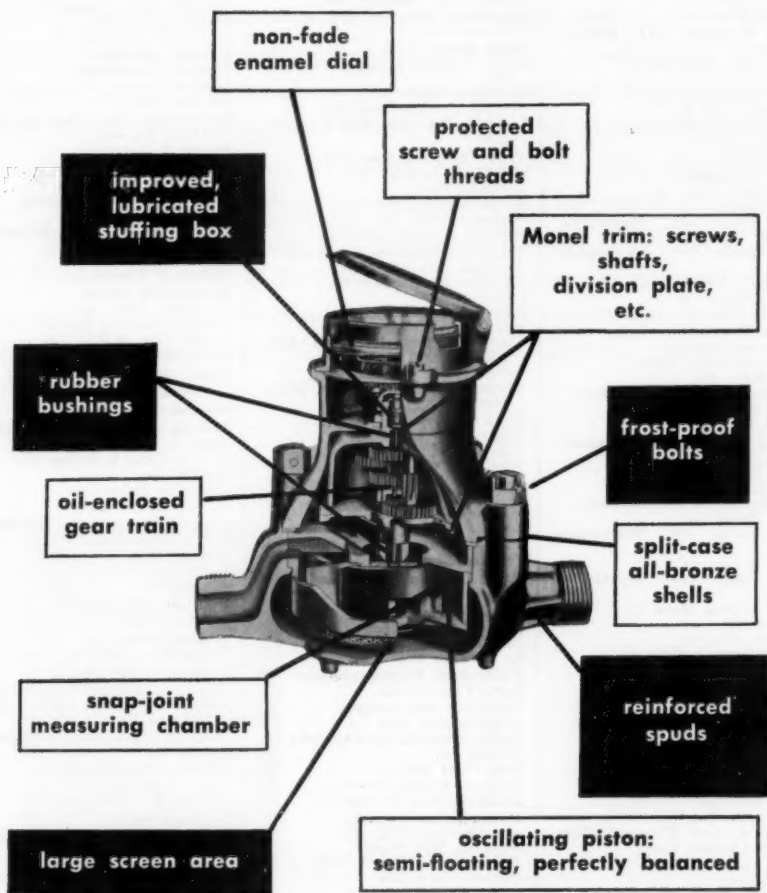
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**Recorders, Gas Density, CO<sub>2</sub>, NH<sub>3</sub>, SO<sub>2</sub>, etc.:**  
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**Permutit Co.**  
**Wallace & Tiernan Inc.**

**Recording Instruments:**  
**Bailey Meter Co.**  
**B-I-F Industries, Inc.—Builders**  
**Fischer & Porter Co.**  
**Simplex Valve & Meter Co.**  
**Wallace & Tiernan Inc.**

**Reservoirs, Steel:**  
**Bethlehem Steel Co.**  
**Chicago Bridge & Iron Co.**  
**Graver Tank & Mfg. Co.**  
**Pittsburgh-Des Moines Steel Co.**

**Sand Expansion Gages; see Gages**

**Sleeves; see Clamps**

**Sleeves and Valves, Tapping:**  
**James B. Clow & Sons**  
**M & H Valve & Fittings Co.**  
**Mueller Co.**  
**Rensselaer Valve Co.**  
**A. P. Smith Mfg. Co.**

**Sludge Blanket Equipment:**  
**Eimco Corp., The**  
**General Filter Co.**  
**Inflico Inc.**  
**Permutit Co.**

**Sodium Aluminate:**  
**Nalco Chemical Co.**

**Sodium Chloride:**  
**International Salt Co., Inc.**

**Sodium Fluoride:**  
**American Agricultural Chemical Co.**  
**General Chemical Div., Allied Chemical Corp.**

**Sodium Hexametaphosphate:**  
**Calgon Co.**

**Sodium Hypochlorite:**  
**Jones Chemicals, Inc.**  
**Wallace & Tiernan Inc.**

**Sodium Silicate:**  
**General Chemical Div., Allied Chemical Corp.**  
**Philadelphia Quartz Co.**

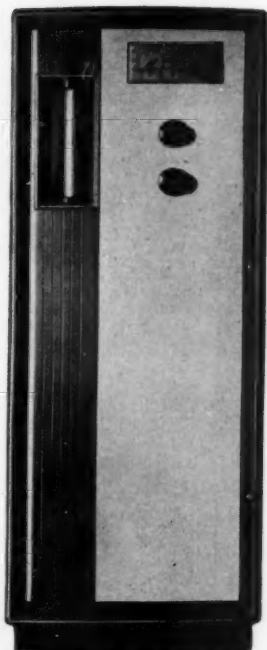
**Sodium Silicofluoride:**  
**American Agricultural Chemical Co.**  
**General Chemical Div., Allied Chemical Corp.**  
**Tennessee Corp.**

**Softeners:**  
**Dorr-Oliver Inc.**  
**General Filter Co.**  
**Hungerford & Terry, Inc.**  
**Permutit Co.**  
**Roberts Filter Mfg. Co.**  
**Walker Process Equipment, Inc.**

**Softening Chemicals and Compounds:**  
**Calgon Co.**  
**General Filter Co.**  
**International Salt Co., Inc.**  
**Nalco Chemical Co.**  
**Permutit Co.**  
**Tennessee Corp.**

**Standpipes, Steel:**  
**Bethlehem Steel Co.**  
**Chicago Bridge & Iron Co.**  
**Graver Tank & Mfg. Co.**  
**Pittsburgh-Des Moines Steel Co.**

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Hays Mfg. Co.  
Mueller Co.

**Storage Tanks: see Tanks****Strainers, Suction:**

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R. D. Wood Co.

**Surface Wash Equipment:**

Golden-Anderson Valve Specialty Co.  
Permutit Co.

**Swimming Pool Sterilization:**

B-I-F Industries, Inc.—Builders  
B-I-F Industries, Inc.—Omega  
B-I-F Industries, Inc.—Proportion-  
ers

Fischer & Porter Co.  
Wallace & Tiernan Inc.

**Tank Painting and Repair:**

Koppers Co., Inc.  
National Tank Maintenance Corp.

**Tanks, Prestressed Concrete:**

Preload Co., Inc.

**Tanks, Steel:**

Bethlehem Steel Co.  
Chicago Bridge & Iron Co.  
Graver Tank & Mfg. Co.  
Morgan Steel Products, Inc.  
Pittsburgh-Des Moines Steel Co.

**Tapping-Drilling Machines:**

Hays Mfg. Co.  
Mueller Co.  
A. P. Smith Mfg. Co.

**Tapping Machines, Corp.:**

Hays Mfg. Co.  
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**Taste and Odor Removal:**

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B-I-F Industries, Inc.—Proportion-  
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General Filter Co.  
Industrial Chemical Sales Div.  
Permutit Co.  
Wallace & Tiernan Inc.

**Turbidimetric Apparatus (For Turbidity and Sulfate Determinations):**

Wallace & Tiernan Inc.

**Turbines, Steam:**

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DeLaval Steam Turbine Co.

**Valve Boxes:**

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M & H Valve & Fittings Co.  
Mueller Co.  
Rockwell Mfg. Co.  
A. P. Smith Mfg. Co.  
Trinity Valley Iron & Steel Co.  
R. D. Wood Co.

**Valve-Inserting Machines:**

Mueller Co.  
A. P. Smith Mfg. Co.

**Valve-Operating Units:**

B-I-F Industries, Inc.  
Filtration Equipment Corp.  
Wachs, E. H., Co.  
Wheeler, C. H., Mfg. Co.

**Valves, Altitude:**

Allis-Chalmers Mfg. Co., Hydraulic  
Div.  
Golden-Anderson Valve Specialty Co.  
Ross Valve Mfg. Co., Inc.

**Valves, Butterfly, Check, Flap,**

**Foot, Hose, Mud and Plug:**  
Allis-Chalmers Mfg. Co., Hydraulic  
Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

DeZurik Corp.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamil-

ton

Henry Pratt Co.

Rockwell Mfg. Co.

R. D. Wood Co.

**Valves, Detector Check:**

Hersey-Sparling Meter Co.

**Valves, Electrically Operated:**

Allis-Chalmers Mfg. Co., Hydraulic  
Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

**Valves, Float:**

James B. Clow & Sons

Golden-Anderson Valve Specialty Co.

Henry Pratt Co.

Rockwell Mfg. Co.

Ross Valve Mfg. Co., Inc.

**Valves, Gate:**

James B. Clow & Sons

Darling Valve & Mfg. Co.

Dresser Mfg. Div.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

**Valves, Hydraulically Oper-**

**ated:**

Allis-Chalmers Mfg. Co., Hydraulic  
Div.

B-I-F Industries, Inc.—Builders

James B. Clow & Sons

Darling Valve & Mfg. Co.

DeZurik Corp.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

F. B. Leopold Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamil-

ton

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

**Valves, Large Diameter:**

Allis-Chalmers Mfg. Co., Hydraulic  
Div.

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

Kennedy Valve Mfg. Co.

M & H Valve & Fittings Co.

Mueller Co.

Pelton Div., Baldwin-Lima-Hamil-

ton

Henry Pratt Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

**Valves, Regulating:**

Allis-Chalmers Mfg. Co., Hydraulic  
Div.

DeZurik Corp.

Golden-Anderson Valve Specialty Co.

Mueller Co.

Henry Pratt Co.

Rockwell Mfg. Co.

Ross Valve Mfg. Co.

**Valves, Swing Check:**

James B. Clow & Sons

Darling Valve & Mfg. Co.

Golden-Anderson Valve Specialty Co.

M & H Valve & Fittings Co.

Mueller Co.

Rockwell Mfg. Co.

A. P. Smith Mfg. Co.

R. D. Wood Co.

**Venturi Tubes:**

B-I-F Industries, Inc.—Builders

Rockwell Mfg. Co.

Simplex Valve & Meter Co.

**Waterproofing:**

Inertel Co., Inc.

Koppers Co., Inc.

Plastics & Coal Chemicals Div.,

Allied Chemical Corp.

**Water Softening Plants; see**

**Softeners**

**Water Supply Contractors:**

Layne & Bowler, Inc.

**Water Testing Apparatus:**

LaMotte Chem. Products Co.

Wallace & Tiernan Inc.

**Water Treatment Plants:**

American Well Works

Chain Belt Co.

Chicago Bridge & Iron Co.

Dorr-Oliver Inc.

Eimco Corp., The

General Filter Co.

Hungerford & Terry, Inc.

Inflico Inc.

Permutit Co.

Pittsburgh-Des Moines Steel Co.

Roberts Filter Mfg. Co.

Walker Process Equipment, Inc.

Wallace & Tiernan Inc.

**Well Drilling Contractors:**

Layne & Bowler, Inc.

**Well Reconditioning and**

**Formation Testing:**

Halliburton Co.

Layne & Bowler, Inc.

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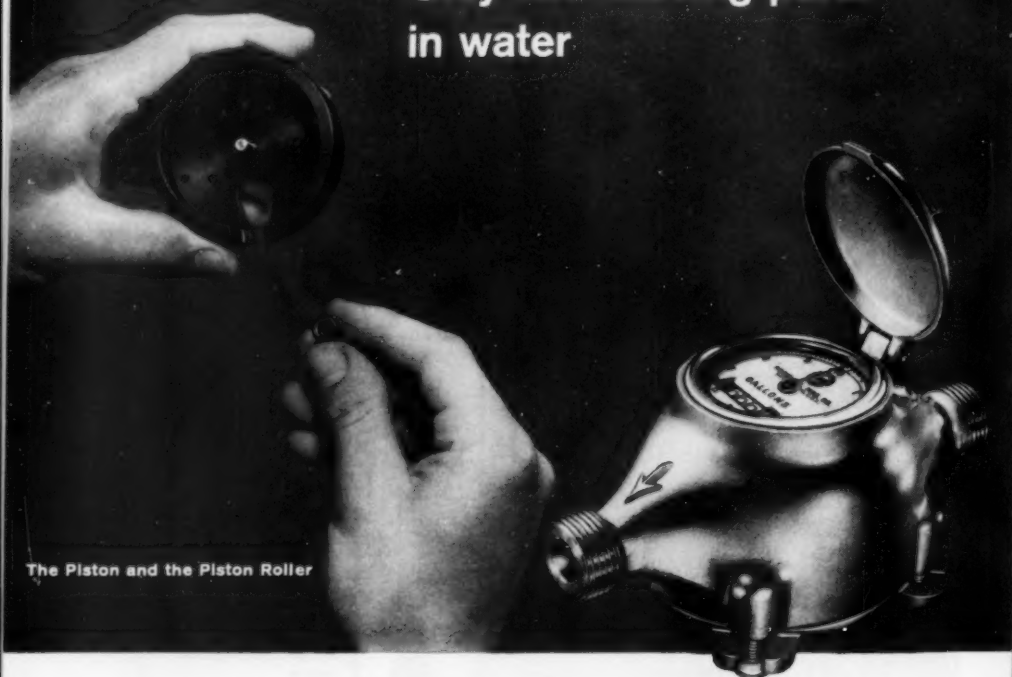
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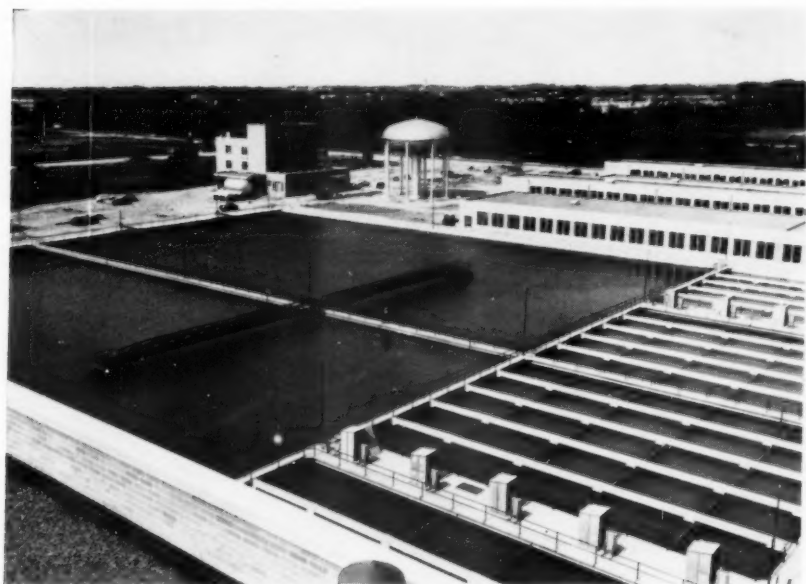
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Consulting Engineers: Morris Knowles Inc., Pittsburgh, Pa. Contractors: McCloskey and Company, Philadelphia, Pa.



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